Chapter 2: Region Description

Overview and Boundaries

The Inyo-Mono IRWM planning region is not exactly what most Americans picture when they think of California. Located east of the Sierra Nevada, the region is isolated from the population, economic activity, politics, and even precipitation of much of California. The region is characterized by very low population density compared to most of the state and vast open spaces. Except for the steep mountain front immediately east of the Sierra Nevada crest, the region is arid, with portions classified as hyper-arid. However, snowmelt runoff from the Sierra Nevada flows into some parts of the region with little direct precipitation. Water from the three largest rivers of the region is largely exported to Nevada and southern California. Consequently, limited water supplies as well as a low proportion of private land ownership have constrained local land use and human settlement. The towns and communities of the region are located either where water was available or where some other exploitable resource outweighed concerns about water supply. Many of the small water systems serving communities of the region suffer from "dis-economies of small-scale" where the tiny customer base is insufficient to meet basic technical, financial and managerial needs to maintain the system. Limited economic opportunities, particularly in tribal communities, further compound the difficulties of building and operating residential water delivery systems to a standard that most Californians take for granted.

Diversity is a key descriptor of the physical geography of the Inyo-Mono IRWM planning region. The area includes the topographically highest and lowest points of California (and the contiguous United States), places with the highest summer temperatures in the country (Death Valley) and occasionally the lowest winter temperatures in the country (Bodie), deep winter snowpacks along the Sierra Nevada crest, and entire years without rainfall in some of the desert portions. These extremes are within a couple of hundred miles of each other.

Explanation of Regional IRWM Boundary

The Inyo-Mono IRWM planning region covers a large area of the central California portion of the western Great Basin. The planning region consists of several large watersheds with internal drainage and no natural outlet to an ocean. The principal river basins or watersheds of the planning area include (from north to south): West Walker River, East Walker River, Mono Basin, Owens River, Amargosa River and Death Valley, Panamint Valley, and Indian Wells Valley. Several other closed basins are included in the southern portion of the planning area.

The vast area of the Inyo-Mono planning region (about 11 percent of California's total area) seemed appropriate when initially determining the extent of the region. Besides the geographic position as the western portion of the Great Basin, the region's residents have long self-identified their home as "the eastern Sierra" or "eastern California". Because of their common geographic isolation away from the larger cities and urban areas of California, Mono and Inyo Counties have developed a regional identity. This "eastern Sierra Nevada" region is well established in a variety of matters such as economic interdependencies, logistics for regional transportation, practicalities for recreation, marketing for tourism, public lands administration, and export of water. In addition, hydrologic boundaries were an obvious determining factor for including the principal watersheds that drain the east side of the Sierra Nevada south of the Carson River basin (which was previously included in the Tahoe-Sierra planning region). The geographical extent of Inyo County into the northern Mojave Desert led to inclusion of several large closed basins wholly or partially within Inyo County. In turn, the watershed boundaries of those basins required including small portions of Kern and San Bernadino counties. The hydrologic linkages and similar water issues throughout the region enable many opportunities for integrated approaches to water resources management. Indeed, we are learning that what DWR has termed the "maximum opportunity for integration" may occur at the level of county government. Both Inyo and Mono Counties may hold the key to facilitating technical, managerial, and financial assistance to the economically disadvantaged as well as tiny communities throughout the planning region.

Boundaries of the Inyo-Mono IRWM planning region enclose Inyo and Mono Counties, northern portions of San Bernardino County and the northeastern corner of Kern County (Figure 1-1). In the northwest, the Inyo-Mono IRWM planning region boundary follows the divide between Alpine and Mono county jurisdictions. On the western edge, the Inyo-Mono IRWM regional boundary follows the crest of the Sierra Nevada and jurisdictional borders of Mono and Inyo Counties with Tuolumne, Mariposa, Madera, Fresno, Tulare and Kern counties. The southwestern boundary also follows the crest of the Sierra Nevada in Inyo County plus a small portion of Kern County. To the south and southeast, the planning region follows watershed boundaries that share more common water resource issues with Inyo County than with other watersheds in Kern and San Bernardino counties. These watersheds include Indian Wells, Searles, Upper Amargosa, Death Valley/Lower Amargosa, Pahrump-Ivanpah, and Panamint Valleys. The east side of the planning area follows the California-Nevada state line. The Nevada side of the watersheds shared by California and Nevada is recognized as an area sharing water resources issues with the Inyo-Mono IRWM planning region and is included in the Inyo-Mono IRWM planning area as an "Area of Interest." Thus, within California, except for the southern boundary where watersheds extend into Kern and San Bernardino Counties, the Inyo-Mono IRWM planning region boundaries are delineated by both watershed and jurisdictional lines. The planning region is wholly contained within the Regional Water Quality Control Board Region 6 (Lahontan) boundaries. Because there is no way to adequately summarize the Water Quality Control Plan for the Lahontan Region (2005) in this document, it is incorporated by reference (http://www.waterboards.ca.gov/lahontan/water_issues/programs/basin_plan/references.shtml).

Inyo County, which makes up most of the Inyo-Mono planning region, is the second largest county in California in total area (10,140 square miles) but has a comparatively small population of about 18,550. Mono County covers approximately 3,100 square miles and has a population of about 14,200 (2010 Census). The region is generally rural and sparsely settled with residents concentrated in and around communities such as Bishop, Ridgecrest, Independence, Big Pine, Lone Pine, Bridgeport, June Lake, and Mammoth Lakes. Primary land uses include livestock grazing (mostly on federally-owned and City of Los Angeles-owned lands), agriculture, and recreation. With the possible exception of industrial-scale solar power development, few major changes in land use and a population growth rate much less than that of the state average are anticipated over this plan's twenty-year planning horizon.

Neighboring / Overlapping IRWM Region Boundaries

Several IRWM planning groups adjoin (or nearly adjoin) the Inyo-Mono region on the west side of the crest of the Sierra Nevada (north to south: Stanislaus–Tuolumne, Yosemite-Mariposa, Madera, Southern Sierra, and Kern County). The Tahoe-Sierra IRWM planning region meets the northern extent of the Inyo–Mono region along the watershed divide between the Carson and Walker river basins. The Mokelumne–Amador–Calaveras IRWM planning region does not share a boundary with the Inyo–Mono IRWM region, but it is close to the northern part of our region. The Mojave IRWM planning region and Inyo–Mono IRWM region share a portion of the Indian Wells–Searles basin within northern San Bernardino County. The Antelope Valley IRWM planning region is within 20 miles of the southern extent of the Inyo–Mono IRWM region in Kern County. The Fremont Basin IRWM planning region was recently formed and shares part of the southern border of the Inyo-Mono planning region. The geographic relationships of the neighboring IRWM regions with the Inyo–Mono IRWM region are illustrated in Figure 1-1.

Most of the neighboring IRWM regions have adopted plans several years ago, and some are in the process of updating those plans under a Round 2 planning grant. The Tuolumne-Stanislaus plan and Antelope Valley update were completed during 2013. A plan for the Yosemite-Mariposa region is being prepared. Inyo-Mono RWMG staff have kept in touch with members of neighboring groups through informal contacts as well as at the Sierra Water Summit and DWR conferences. Instead of providing a snapshot of neighboring efforts as of early 2014, links to the primary websites of neighboring IRWM groups are available in the table below.

Links to neighboring regions *(arrayed from north to south)*	
Tahoe-Sierra	http://www.tiims.org/Work-Groups/Lake-Tahoe-Work-Groups/Lake-Tahoe-Work-Group.aspx?RoleID=159&Page=2
Mokelumne–Amador–Calaveras	http://www.ccwd.org/publications/pub_MokeAmaCalaPlan.html
Tuolumne- Stanislaus	http://www.tudwater.com/projects-development/integrated-regional-water-management-plan/
Yosemite-Mariposa	http://www.mcrcd.net/Pages/IRWMP.aspx
Madera	http://www.madera-id.org/index.php/rwmg
Southern Sierra	http://www.sequoiariverlands.org/resources/irwmp
Kern County	http://www.kernirwmp.com/
Fremont Basin *(RAP approved in Jan. 2014)*	http://www.water.ca.gov/irwm/grants/docs/Archives/Prop84FirstRAPCycle/RAP%20Documents/2011Writeups/Fremont%20Basin%20writeup.pdf
Mojave	http://www.mywaterplan.com/index.html
Antelope Valley	http://www.avwaterplan.org/

Description of Watersheds and Water Systems

Major drainage systems in the region are the Walker, Owens, and Amargosa river systems. The Walker River system flows from the eastern slope of the Sierra Nevada into Nevada where it terminates at Walker Lake. Prior to the construction of the Los Angeles Aqueduct, the Owens River historically terminated at Owens Lake; presently, the Los Angeles Aqueduct is the sole means by which runoff from the region can drain to the Pacific Ocean. The headwaters of the Amargosa River are in Nevada, from which it flows into California, terminating in Death Valley. Numerous other internally drained basins exist wholly or mostly within the region, including Mono, Saline, Eureka, Deep Springs, Indian Wells, Panamint, and Searles Valleys. Naturally occurring perennial lakes are uncommon except at high elevations in the Sierra Nevada and in the adjacent valleys receiving runoff from the eastern slope of the Sierra Nevada. The largest natural lake in the region is Mono Lake. Historically, a large lake existed at Owens Lake; however, irrigation for agriculture, drought, and diversions from tributaries to the Owens River and the Owens River itself resulted in the lake declining to a small brine pool in the 1920s and 1930s. Surface water is rare and ephemeral in the arid desert basins south and east of Owens Valley.

The Inyo-Mono IRWM region is comprised of 12-18 large hydrographic units or major watersheds, depending on how certain basins are lumped together in the watershed-delineation schemes of the U.S. Geological Survey and Calwater (Tables 2-1, 2-2, and 2-3). The Calwater basins are illustrated in Figure 1-1.

Table 2-1. Inyo-Mono IRWM region watersheds based on USGS HUC designation.

USGS Hydrologic Unit Code	Watershed Name
16050301	East Walker
16050302	West Walker
16060010	Fish Lake – Soda Springs Valleys
18090101	Mono Lake
18090102	Crowley Lake
18090103	Owens Lake
18090201	Eureka - Saline Valleys
18090202	Upper Amargosa
18090203	Death Valley - Lower Amargosa
18090204	Panamint Valley
18090205	Indian Wells - Searles Valleys
16060015	Ivanpah - Pahrump Valleys

Table 2-2. Inyo-Mono IRWM region watersheds based on Calwater designation.

Calwater Code	Watershed Name
121 8630	East Walker River
122 8631	West Walker River
134 9601	Mono
135 9602	Adobe
136 9603	Owens
137 9604	Fish Lake
138 9605	Deep Springs
139 9606	Eureka
140 9607	Saline
141 9608	Race Track
142 9609	Amargosa
143 9610	Pahrump
144 9611	Mesquite
146 9613	Owlshead
153 9620	Ballarat
154 9621	Trona
155 9622	Coso
156 9623	Upper Cactus
157 9624	Indian Wells

Table 2-3. Correspondence between USGS and Calwater naming conventions

USGS HUC	Calwater
East Walker	East Walker River
West Walker	West Walker River
Fish Lake – Soda Springs	Fish Lake
Mono Lake	Mono
Mono Lake	Adobe
Crowley Lake	Owens
Owens Lake	Owens
Eureka-Saline	Deep Springs
Eureka-Saline	Eureka
Eureka-Saline	Saline
Eureka-Saline	Racetrack
Upper Amargosa	Amargosa
Death Valley – Lower Amargosa	Amargosa
Death Valley – Lower Amargosa	Owlshead
Panamint Valley	Ballarat
Indian Wells – Searles	Trona
Indian Wells – Searles	Coso
Indian Wells – Searles	Upper Cactus
Indian Wells – Searles	Indian Wells
Ivanpah - Pahrump	Pahrump
Ivanpah - Pahrump	Mesquite

The only hydrographic units that are not entirely included in the IRWM planning region are those that cross the Nevada border. The other units are fully contained in the planning region and largely define the rationale for the extent of the planning region. Although the inclusion of areas in southeast Inyo County, northern San Bernardino County, and northeastern Kern County was debated due to the remote nature of the region, it was decided by the RWMG that it was logical to include all of Inyo County yet still make the boundary watershed-based (thus including parts of San Bernardino and Kern Counties). These watersheds include Indian Wells Valley, Searles, Upper Amargosa, Death Valley/Lower Amargosa, Pahrump-Ivanpah, and Panamint Valley. A similar debate and resolution occurred for the northern part of the region in the East Walker River and West Walker River units.

The Inyo-Mono IRWM planning region not only reflects watershed boundaries but areas of common water management history and interest as well. All the water in the western portion of our region, east of the Sierra Nevada crest, flows east into water bodies that are important for fisheries, stream habitat, recreation, and water supply for communities in Nevada, southern California, and the planning region itself. The watersheds in the south of the planning region share common issues such as low population density, rural water management, large tracts of federal land, an arid climate, and complex topography. One of the larger hydrographic units in the planning region is the Owens, which spans two counties and provides water to the Los Angeles Aqueduct (LAA) and the four million residents of Los Angeles. Through the Los Angeles Department of Water and Power (LADWP), the City of Los Angeles is one of the participants in Inyo-Mono RWMG meetings, but is not yet a signatory to the IRWM group. The Inyo-Mono IRWM region boundaries include all water-related infrastructure associated with the source waters of the LAA.

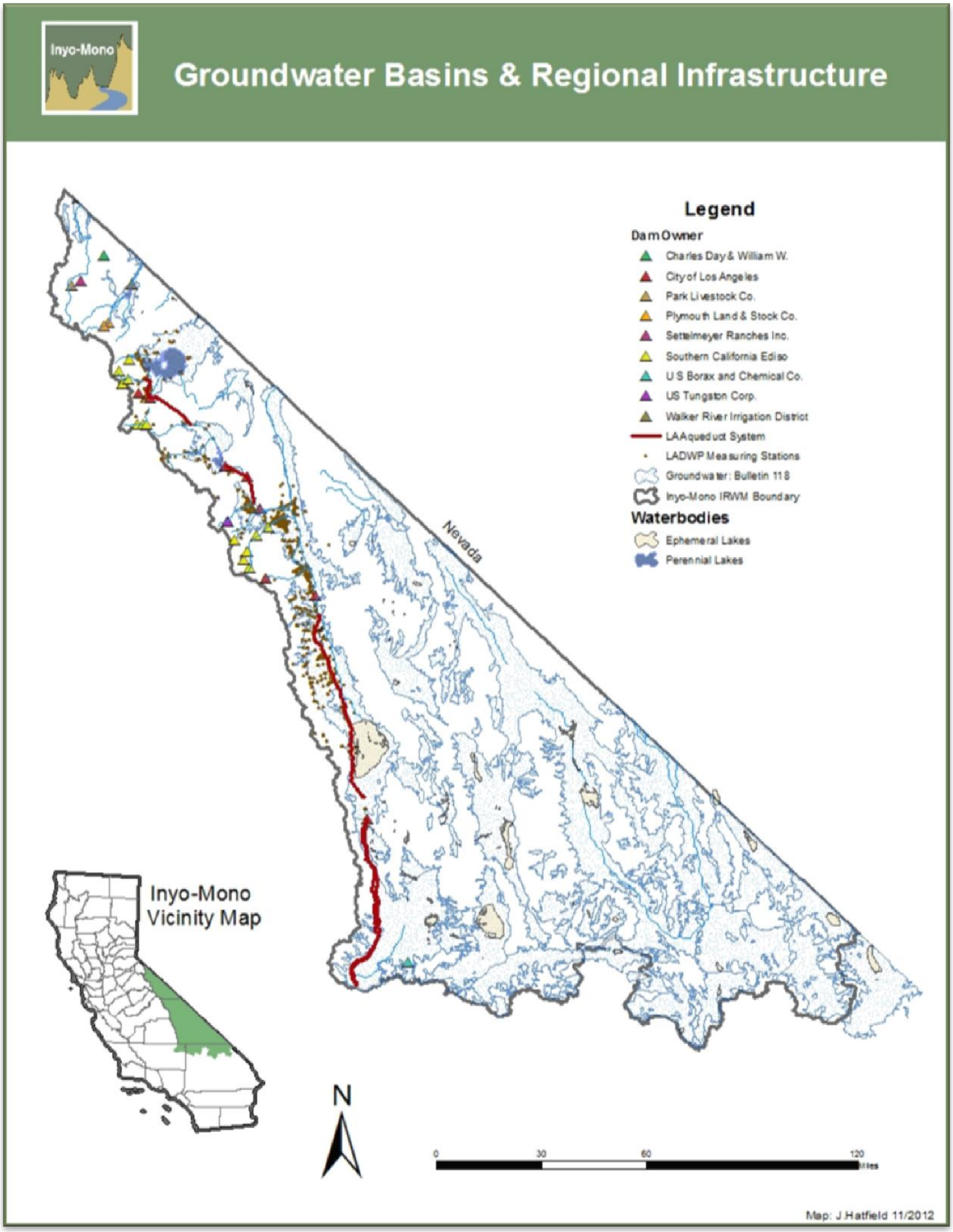
Numerous groundwater basins underlie the region, and include Antelope Valley, Bridgeport Valley, Mono Basin, Long Valley, Owens Valley, Mojave, Indian Wells and Searles Valleys, and California Valley Groundwater Basins. California DWR Bulletin 118 groundwater basin areas are shown on Figure 2-1 and listed in Table 2-4. Inyo and Mono Counties have not adopted Groundwater Management Plans, which use existing government bodies and authorities to proactively monitor and manage groundwater resource issues. Instead, the counties have groundwater ordinances in place, which employ land-use planning and police powers of locally elected county boards to manage groundwater resources. Inyo County has a groundwater management agreement with the City of Los Angeles. The Mammoth Community Water District completed a groundwater management plan for the Mammoth Basin watershed in July 2005. More recent efforts responding to the California Statewide Groundwater Elevation Monitoring (CASGEM) requirements are discussed in Chapter 4.

Table 2-4. DWR Bulletin 118 Groundwater basins in the Inyo-Mono planning region.

Basin Number	Basin Name	Basin Number	Basin Name
6-7	Antelope Valley	6-55	Coso Valley
6-8	Bridgeport Valley	6-56	Rose Valley
6-9	Mono Valley	6-57	Darwin Valley
6-10	Adobe Lake Valley	6-58	Panamint Valley
6-11	Long Valley	6-61	Cameo Area
6-12	Owens Valley	6-62	Race Track Valley

Basin Number	Basin Name	Basin Number	Basin Name
6-13	Black Springs Valley	6-63	Hidden Valley
6-14	Fish Lake Valley	6-64	Marble Canyon Area
6-15	Deep Springs Valley	6-65	Cottonwood Spring Area
6-16	Eureka Valley	6-66	Lee Flat
6-17	Saline Valley	6-68	Santa Rosa Flat
6-18	Death Valley	6-70	Cactus Flat
6-19	Wingate Valley	6-71	Lost Lake Valley
6-20	Middle Amargosa Valley	6-72	Coles Flat
6-21	Lower Kingston Valley	6-73	Wild Horse Mesa Area
6-22	Upper Kingston Valley	6-74	Harrisburg Flats
6-23	Riggs Valley	6-75	Wildrose Canyon
6-24	Red Pass Valley	6-76	Brown Mountain Valley
6-25	Bicycle Valley	6-77	Grass Valley
6-26	Avawatz Valley	6-78	Denning Spring Valley
6-27	Leach Valley	6-79	California Valley
6-28	Pahrump Valley	6-80	Middle Park Canyon
6-29	Mesquite Valley	6-81	Butte Valley
6-30	Ivanpah Valley	6-82	Spring Canyon Valley
6-34	Silver Lake Valley	6-84	Greenwater Valley
6-35	Cronise Valley	6-85	Gold Valley
6-49	Superior Valley	6-86	Rhodes Hill Area
6-50	Cuddeback Valley	6-88	Owl Lake Valley
6-51	Pilot Knob Valley	6-105	Slinkard Valley
6-52	Searles Valley	6-106	Little Antelope Valley
6-53	Salt Wells Valley	6-107	Sweetwater Flat
6-54	Indian Wells Valley		

Figure 2-1: DWR Bulletin 118 groundwater basins of the planning region



The above map depicts Bulletin 188 Groundwater basins as well as major water-related infrastructure and select water bodies in the region.

Major Water Systems

Water storage and transfers in the Inyo-Mono IRWM planning area are dominated by the Los Angeles (LA) Aqueduct system. All other water engineering within the area is minor by comparison. The project involves extensive infrastructure (Figure 2-1) and vast land holdings (Figure 2-2). Major components of the Los Angeles Department of Water and Power (LADWP) water export and power generation system include a series of diversions and a tunnel for exporting water from the Mono Basin to the Owens River headwaters; the Crowley Lake reservoir in Long Valley; diversions in the Owens River Gorge for power generation; hydropower generation on Big Pine, Division, and Cottonwood Creeks; the Tinemaha, Pleasant Valley, and Haiwee Reservoirs; extensive groundwater pumping capacity; and the Los Angeles Aqueduct (Figure 2-1). Los Angeles' land and water ownership and extensive infrastructure along the east slope of the Sierra link many water management issues in the western part of the Inyo-Mono IRWM planning region.

Within the Mono Basin, the LADWP constructed diversion works on the main tributaries to Mono Lake (except for Mill Creek), a dam creating Grant Lake, and a tunnel to the Upper Owens watershed. Diversions out of the Mono Basin began in 1941 and greatly increased following completion of the second aqueduct in the Owens Valley in 1970. Diversions were halted by court order from 1989 to 1994. Starting in 1995, diversions up to 16,000 acre-feet per year resumed under California State Water Resources Control Board Decision 1631

Southern California Edison operates a series of dams and powerhouses on Mill Creek, Lee Vining Creek, Rush Creek, and Bishop Creek. The Mammoth Community Water District regulates storage in and discharge from a relatively small lake above the town of Mammoth Lakes..

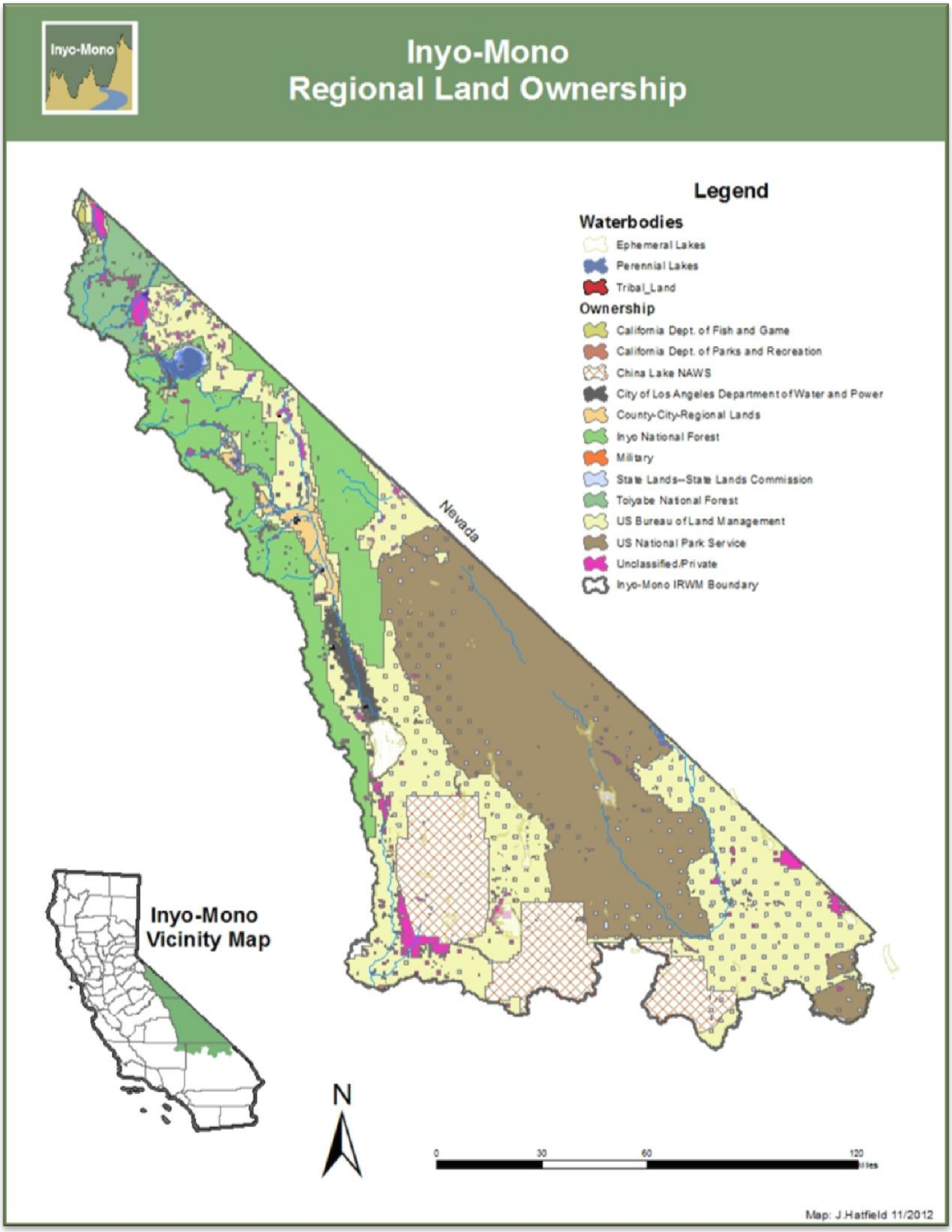
In the upper Owens River watershed (commonly defined as upstream of the Owens Gorge), Crowley Lake was created by construction of Long Valley dam in the early 1940s. The reservoir is the main storage within the LA Aqueduct system and has a capacity of 183,000 acre-feet. At the other end of the Owens Gorge, Pleasant Valley Reservoir was built in 1955 to modulate flows released from the hydroelectric facilities in the Owens Gorge. This reservoir can store up to 3,825 acre-feet.

Surface and groundwater exports from the Owens Valley to Los Angeles vary greatly from year to year, with an average of about 356,000 AF between 1970 and 2011 (LADWP, 2011a). Since the dry period of 1987 to 1992, exports have been well below that average in most years. Between 2000 and 2011, export volumes have been as low as 110,000 AF in 2007 and above the 40-year average in 2005, 2006, and 2011 (Harrington, 2009; LADWP, 2011a).

LADWP provides water for different uses within the Owens Valley such as irrigation, livestock watering, recreation, wildlife, environmental enhancement and mitigation (with respect to groundwater pumping) projects, the Lower Owens River Project, and an extensive dust abatement project on the Owens Lake playa that currently relies heavily on shallow flooding to control dust. Water use by LADWP within the Owens Valley in the 2011-12 runoff year was estimated to be 202,000 AF. That total was distributed among the uses as 95,000 AF potentially available (less was applied) for the dust abatement project, 55,000 AF for irrigation, 16,500 AF for the Lower Owens River Project, 11,000 AF for stockwater, 10,500 AF for enhancement and mitigation projects, 10,400 AF for recreation and wildlife, and 3,900 AF for Indian lands (LADWP, 2011a).

At the northern end of the Inyo-Mono IRWM region, both the West Walker and East Walker Rivers have been developed for irrigation. Stream diversions, canals, and distribution ditches have irrigated Antelope and Bridgeport valleys for more than a century. In the 1920s, the Walker River Irrigation District constructed reservoirs on both the West Walker and East Walker Rivers. Although water stored in Topaz and Bridgeport reservoirs is exported from the stateline-defined watersheds included for the Inyo-Mono IRWM planning area, that water is applied to irrigation within the Walker River Basin, downstream of the state border in Nevada.

Figure 2-2. Land ownership of the Inyo-Mono planning region.



This map illustrates the small percentage of privately owned land in the Inyo-Mono region of which LADWP owns a large proportion.

Description of Internal Boundaries

Political Boundaries

The Inyo-Mono IRWM region includes Inyo and Mono counties in their entirety and small portions of Kern and San Bernardino counties (Figure 1-1). Ridgecrest, Bishop, and Mammoth Lakes are the only incorporated cities or towns in the region and have populations of about 30,000, 3,900, and 8,200, respectively.

Land Ownership and Administrative Boundaries

Almost all the Inyo-Mono IRWM region is public land administered by agencies including USDI-Bureau of Land Management, USDI-National Park Service, USDA-Forest Service, Department of Defense, Los Angeles Department of Water and Power, California State Lands Commission, California Department of Fish and Wildlife, and California Department of Parks and Recreation. Compared to other parts of California, there is remarkably little private or tribal land. The general ownership patterns are illustrated in Figure 2-2. Figure 2-2 also shows the locations of the two cities (Ridgecrest and Bishop), one town (Mammoth Lakes), and some of the small communities (north to south: Coleville, Bridgeport, Lee Vining, Benton, Tom's Place, Laws, Big Pine, Independence, Lone Pine, Keeler, Death Valley, Cartago, Olancha, Shoshone, Tecopa, Trona, and Inyokern).

Several dozen small water districts and other water purveyors (if aggregated) cover less than one percent of the area of the Inyo-Mono IRWM region (Figure 2-1). Most of these entities have considerable financial and operational difficulties related to their small scale and modest customer base. The Indian Wells Water District dwarfs the other districts in size and population served (approximately 30,000 people). The Mammoth Community Water District and the Indian Wells Valley Water District are the only two urban water management districts (serving more than 3,000 connections) in the region.

Descriptive Geography

With respect to climate and hydrology, the Inyo-Mono region can be split into two broad zones: eastern Sierra Nevada and northern Mojave Desert. Much of the description that follows in this section generalizes conditions within these two zones. The northern part of the Inyo-Mono region (West Walker, East Walker, Mono, and Owens watersheds) is the eastern Sierra Nevada zone. The southern and southeastern portions of the planning area (Indian Wells Valley, Searles, Upper Amargosa, Death Valley/Lower Amargosa, Pahrump-Ivanpah, and Panamint Valley watersheds) are the northern Mojave Desert zone. Largely because of the far-greater availability of water resources in the eastern Sierra Nevada zone, there is a correspondingly greater amount of information available for the watersheds in the eastern Sierra Nevada zone than those in the northern Mojave Desert zone.

Much of the otherwise uncited information in this section is excerpted from assessments of four watersheds in Mono County (Kattelmann, 2007a, 2007b, 2007c; Kattelmann and Johnson, 2012). Because of these sources, there is an obvious bias toward Mono County. This bias results simply from the availability of information. The comparatively small amount of relevant information about the northern Mojave Desert portion of the planning area is reflected in the small proportion of text devoted to the southern area.

Climate and Potential for Climatic Change

The climate of a region can be considered to be the "average" weather as well as the extremes over some period of time. We are usually limited to the historical period and then often only a few decades during which some systematic measurements of precipitation and temperature were made and recorded. The term "normal" is a convention that typically includes only the past 30 years, although within the region, the Los Angeles Department of Water and Power uses a 50 year average. Similar to the warnings that accompany a financial investment prospectus, we should remember that past climate is no guarantee of future conditions. Nevertheless, recent climate is the best indicator we have of what to expect in the near future. Where inferences are available regarding prehistoric climate, such information is valuable to suggest the range of extremes that are possible in a given region.

Most of the eastern Sierra Nevada region is subject to the Mediterranean-type climate of California, characterized by wet, cool winters and warm, dry summers, and is subject to the orographic rain-shadow effect of being on the lee side of the Sierra Nevada with respect to the prevailing southwest-to-northeast storm direction. An exception to the general rain-shadow pattern occurs when small storms travel south from eastern Oregon into Nevada and then produce upslope flow and orographic lifting on the eastern slope of the Sierra Nevada. Storms typically begin to affect California in October and November and occur at irregular intervals through March in most years. An average of 15 to 20 discrete storms affects central California each winter. Intervals of clear, cool weather lasting one to several days separate these storms, although an extended dry period of three to six weeks occurs in many winters. December, January, and February tend to be the months of greatest precipitation. Storm frequency and intensity typically decrease in April and May, although a few significant storms can occur during the spring. Rain/snow levels of 5,000 to 7,000 feet are typical for most winter storms. The amount of precipitation has been highly variable from year to year.

Summers tend to be dry and warm because of the dominance of high pressure and the absence of a storm track through California during the summer months. Convective thunderstorms occasionally develop when adequate moisture enters the region. When the "Arizona monsoon" pattern delivers moist air far enough west and north, significant thunderstorms can occur each afternoon and evening for several days at a time in the eastern Sierra Nevada.

Precipitation is greatest in the headwater areas just east of the Sierra Nevada crest. There is a steeply declining gradient in precipitation with distance east from the crest. This rain-shadow effect is largely due to the descent of air in the lee of the crest, which causes warming and evaporation of clouds (Powell and Klieforth, 2000). The areas immediately east of the crest also benefit from wind-driven carryover of precipitation that resulted from the lifting and cooling on the west side of the Sierra Nevada and some wind transport of snow initially deposited west of the crest. Precipitation increases again as air rises up the various ranges on the western edge of the Basin and Range geologic province (*e.g.,* Sweetwater Mountains, Bodie Hills, Glass Mountains, White-Inyo Mountains).

Annual precipitation measured at a few automated sites and inferred from snowpack measurements has mean values exceeding 30 inches per year above 9,000 feet in the Sierra Nevada and tends to decline from north to south. Annual precipitation amounts decline rapidly to the east of the crest with average amounts of 8 to 12 inches in Antelope Valley, 9 inches at Bridgeport, 8 to 15 inches around Mono Lake, 10 inches at Long Valley Dam, and 5 inches at Bishop.

The water equivalence of the snowpack (the depth of water at a point if the snowpack is melted) is measured at about 400 locations throughout the snow zone of California by the Department of Water Resources and cooperating agencies. These measurements are made near the beginning of each month in the winter to supply data for forecasting the amount of snowmelt runoff in streams between April and July. Measurements taken near the beginning of April have been found to approximate the peak accumulation of the snowpack. On average, storms contribute little additional snowfall after April 1, and snowmelt begins to deplete the water storage of the snowpack in early April. Therefore, the April 1 snow survey measurements have been used in many hydrologic studies as a proxy for the season-long accumulation of precipitation in mountain areas where almost all of the precipitation falls as snow and accumulates throughout the winter (the caveat being that some snow melts and sublimates during the winter, thereby reducing the April 1 snowpack). For example, the Mammoth Pass snow course has a continuous record of 83 years (1931 to current [2014]). The long-term April 1 (peak accumulation) average at this site is 43 inches, with a minimum in 1977 of 8.6 inches and a maximum in 1969 of 86.5 inches. Long-term averages of April 1 snow water equivalence from snow courses in the major river basins range from 17 to 51 inches in the West Walker, 18 to 39 inches in the East Walker, 27 to 34 inches in the Mono Basin, 11 to 42 inches in the Upper Owens, and 10 to 31 inches in the Owens south of Crowley Lake. These values are only indicative of precipitation in the highest portions of the respective watersheds just east of the crest of the Sierra Nevada.

The northern Mojave desert zone is characterized by minimal rainfall and great variability in what rainfall does occur. The few precipitation measuring stations in the zone show average annual amounts of only a few inches: 2.4 inches at Furnace Creek in Death Valley, 4.1 inches at Trona, 4.8 inches at Inyokern, 6.7 inches at Mojave, and 6.9 inches at Randsburg (source: http://usclimatedata.com). At a U.S. Geological Survey research station in the upper Amargosa watershed (in Nevada, downstream of Beatty), annual precipitation averaged 4.4 inches from 1981 to 2005 and ranged from 0.14 inches to 8.9 inches (Johnson, et al., 2007). Although the bulk of a year's precipitation tends to fall during the winter months, summer thunderstorms can contribute significant quantities of water to isolated areas every few years. In general, summer precipitation tends to be a greater proportion of the annual total in the eastern part of the Mojave zone (Hereford, et al., 2003). The sparse array of precipitation gages cannot capture any indication of the variability of rainfall over the desert zone, but measured rainfall in individual summer seasons varied from 0 to 5 inches (Hereford, et al., 2003). Geomorphic evidence, such as debris flows in some canyons but not adjacent ones, suggests how rainfall exceeding average yearly amounts can occur in a few hours in small areas. Conversely, several months may pass without any rainfall in a particular area.

Within the Indian Wells Valley watershed, average annual precipitation varies from 5 to 10 inches per year, with less than 5 inches per year in the Ridgecrest/China Lake area and in the El Paso Mountains to the south, up to about 6 inches per year in the Argus Range to the east and the Coso Range to the north, and up to about 10 inches per year in the Sierra Nevada (Indian Wells Valley Water District 2002, cited by Couch, et al., 2003). Most of the precipitation occurs between October and March, with a typical peak in January.

Analysis of all available precipitation records from stations in the Mojave Desert (Hereford, et al., 2003) demonstrated substantial variation throughout the 20th century. There appear to have been some persistent patterns in precipitation during the past century: 1893-1904 was relatively dry, 1905-1941 was relatively wet, 1942-1975 was mostly dry, and 1976-1998 was the wettest portion of the century (Hereford, et al., 2003).

Throughout the region, air temperatures vary markedly both seasonally and daily. There is also considerable variation among years for any given day, making averages a poor descriptor (Howald, 2000a). Records of air temperature are even more limited than those of precipitation or snowpack water storage. The small amounts of water vapor in the air and the absence of large water bodies allow the air temperature to fluctuate greatly between day and night compared to more humid parts of the country.

Data from a few stations within the eastern Sierra Nevada portion of the Inyo-Mono planning area illustrate the general air-temperature regime. Parts of the East Walker River watershed are well-known as cold spots in California. Bridgeport and Bodie are occasionally in the winter-season news as the coldest locations in the nation when the upper Midwest is unusually warm. Over the past century at the Bridgeport climate station, the average annual maximum temperature was 62°F and the average annual minimum temperature was 24°F. The recorded extremes at Bridgeport have been 96°F and -37°F (California Department of Water Resources, 1992). At Bodie, the average annual maximum temperature was 56°F and the average annual minimum temperature was 19°F (Western Regional Climate Center at http://www.wrcc.dri.edu).

The mean temperature at Cain Ranch, the station in the Mono Basin with the longest record of air temperature, from 1931 through 1979, was 43ºF with a maximum of 94ºF and a minimum of -18ºF (LADWP, 1987). Two sites in and near Lee Vining have monitored air temperature for the periods 1950-88 and 1988-2005. The averages from these sites are remarkably close with an average maximum of about 62ºF and an average minimum of about 34ºF (data from Western Regional Climate Center: http://www.wrcc.dri.edu).

A description of air temperatures at Valentine Camp in Mammoth Lakes (Howald, 2000a) provides some insight into the temperature regime of the mid-elevation forest zone. During summer, mean daily maxima ranged between 65°F and 80°F and mean daily minima ranged between 40°F and 50°F. Nighttime low temperatures, especially at ground level, can drop below 32°F at any time of year, although rarely for more than a few hours on even the coldest summer nights. Radiational heat loss in meadows and cold air drainage from surrounding uplands can result in locally low nighttime temperatures. This cold air pooling during periods of low wind is a feature unique to topographically-complex areas. The forest canopy maintains warmer temperatures among the trees. During winter, mean daily maxima ranged between 35°F and 45°F, and mean daily minima ranged between 15°F and 25°F. However, on many winter days, air temperatures do not rise above 32°F. In some winters, minimum air temperatures can drop to about -20°F during outbreaks of polar air (Howald, 2000a).

At the Sierra Nevada Aquatic Research Laboratory on Convict Creek south of Mammoth Lakes, average annual air temperatures from 1988 to 1998 ranged from 40°F to 45°F, with a mean of 43°F. The mean summer air temperature was 59°F, and the mean winter temperature was 19°F. Maximum temperatures in summer ranged from 73°F to 85°F, with summer minimum temperatures between 32°F and 43°F. July and August are typically the only frost-free months, although frost may occur at any time of the year. Winter diurnal temperature fluctuations are less than in summer. Daytime high temperatures ranged from 30°F to 52°F, and nighttime lows ranged from 0°F to 23°F.

Table 2-5. Air temperature (°F) for several stations in the northern Mojave Desert zone (source: http://www.wrcc.dri.edu):

	Monthly Maximum		Monthly Minimum		Annual Average	
Site	Winter	Summer	Winter	Summer	Maximum	Minimum
Haiwee	53	92	30	63	73	46
Inyokern	61	99	32	65	81	47
Trona	61	102	34	70	81	52
Randsburg	55	96	36	66	75	51
Wildrose RS	53	93	31	62	72	45
Death Valley	67	114	41	85	91	62

Water loss to the atmosphere is a large component of the annual water balance of watersheds in arid environments. Because of low atmospheric humidity, abundant solar radiation, high air temperatures, and moderate wind speeds, there is great potential for large amounts of water to evaporate throughout the Inyo-Mono planning area, especially in the northern Mojave Desert zone. However, water is usually not available to be evaporated; therefore, actual evapotranspiration (evaporation from open water and soils plus transpiration from plants) is a limited fraction of potential evapotranspiration at the watershed scale.

Potential evapotranspiration as estimated from water loss in evaporation pans exceeds 100 inches per year at two sites in the northern Mojave Desert zone. At Mojave from 1948 to 2005, the average water loss is 112 inches per year, with a monthly high in July of 17 inches. At Death Valley from 1961 to 2005, the average annual amount is 140 inches. At this site, the maximum monthly amount is 21 inches in July (http://www.wrcc.dri.edu/htmlfiles/westevap.final.html).

Actual evapotranspiration has been estimated in a few studies within the Inyo-Mono planning area. In the Mammoth Creek watershed, actual evapotranspiration was estimated to average 13 inches over the watershed area (California Department of Water Resources, 1973). In the Mono Basin, Vorster (1985) estimated an average growing season evapotranspiration rate of 24 inches. In the Bridgeport Valley, annual evapotranspiration has been estimated as about 29 inches (Lopes and Allander, 2009). Evapotranspiration in the Antelope Valley area was estimated as 33,000 AF from agriculture and 3,600 AF from phreatophytes (Glancy, 1971).

Significant water loss occurs where water is available, principally from lakes and from phreatophytes (plants with roots accessing the local water table). Evaporation from the larger natural lakes in the Inyo-Mono planning area has been estimated in a few studies. Open water evaporation from Mono Lake was estimated at about 40-45 inches per year in several studies through the 1960s and at 39 inches per year by the Los Angeles Department of Water and Power (1984). An estimate of 48 inches per year (apparently derived from a 1992 modeling study) was used in an EIR water balance (Jones and Stokes Associates, 1993a: Appendix A). Evaporation from June Lake has been estimated as 38 inches per year (California Department of Water Resources, 1981). Open-water evaporation from lakes above 9,000 feet has been estimated at about 20-25 inches per year, and is limited by ice cover.

Evaporation has also been estimated from some of the region's reservoirs. The average annual total loss at Topaz Lake has been about 69 inches. At Bridgeport Reservoir, with winter ice cover, the average loss has been estimated at 43 inches (Lopes and Allander, 2009). Average annual evaporation from Grant Lake, which also has winter ice cover, has been variously estimated at 26, 36, and 43 inches (Lee, 1969; Los Angeles Department of Water and Power, 1987). Evaporation has been measured by the LADWP at the Long Valley dam during ice-free months with evaporation pans both in the lake and on shore. The pan located on land had an average loss from eight non-freezing months of 41 inches, and the floating pan lost an average of 52 inches over nine non-freezing months (from the same year; Jones and Stokes Associates, 1993a: table 3A-4).

Although water managers would like climate and other environmental conditions to remain "stationary" over time so that measurements in the recent past can indicate what to expect in the future, we are well aware that conditions do change over time. Paleohydrologic studies suggest that both severe floods and extended droughts have occurred in the Inyo-Mono planning area and can certainly happen again. In addition to natural climatic variability, human-induced changes in the atmosphere have the potential to alter future climatic conditions in the area.

The most recent glacial advance peaked about 3,000 years ago (Minnich, 2007). Several lines of vegetation evidence also suggest that period was wetter and cooler than periods before and after. The climate also cooled and had relatively high precipitation during the so-called Little Ice Age, between roughly 1300 and 1800 (Minnich, 2007; USDA-Forest Service, 2011).

Evidence of severe and persistent drought in prehistoric times has been found in the northern part of the planning area, indicating periods of 140 to 220 years with very little precipitation (Stine, 1994). Dozens of Jeffrey pine (*Pinus jeffreyi*) stumps are rooted in the main channel of the West Walker River upstream of Walker. These trees could survive in that location only if streamflow was so low that the roots of the trees were not submerged for more than a few weeks each year. Radiocarbon dating of the wood showed that an older group of trees was alive between about AD 900 and 1100 and another set of trees grew in the bottom of the channel between about AD 1210 and 1350 (Stine, 1994). The channel is narrow and stable enough that changes in the location of the channel cannot explain the presence of the stumps. The age of the trees in the West Walker River corresponds to the age of other old stumps found in Tenaya Lake and near Mono Lake, suggesting that dry conditions during the same periods allowed establishment of trees in other locations in the region (Stine, 1994). In modern times, the period of 1928 through 1934 is regarded as an extended drought within the Walker River basin.

Records of streamflow in the Owens Valley since the 1920s allow comparison of flood peaks over time. There appears to be a cluster of relatively extreme events in the 1970s and 1980s (Kattelmann, 1992). Five of the largest eight to eleven snowmelt floods (in terms of volume) occurred from 1978 to 1986. Five of the smallest thirteen or fourteen snowmelt floods occurred from 1987 to 1991. Instantaneous peak flows show similar clustering. For example, in Rock Creek, four of the ten largest annual floods and three of the six smallest annual floods happened in the 1980s. Such events support theories developed by some climatologists that because of an observed shift in hemispheric flow patterns, extreme events are becoming more common in North America.

As global temperatures continue to rise as a result of anthropogenic increases in atmospheric greenhouse gases, changes in the climate of the Sierra Nevada can be expected. A wide variety of reports issued in the past decade suggest regional temperatures will rise, precipitation will decline, there will be more rain and less snowfall, there will be a smaller snowpack, the snowpack will begin to melt earlier, and the snowpack will melt faster. However, the situation and the underlying physical processes are not quite so simple. For example, snowmelt in the Sierra Nevada has surprisingly little direct response to air temperature. Solar radiation input to the snow surface is a far more important factor in energy exchange (and therefore, snowmelt) than processes involving the temperature of the air. Water managers relying on the water resources of the planning area need to anticipate the possibility of changes in climate and hydrology compared to the recent past, but should not assume that the common predictions of less snow are the only reasonable scenario (see also Chapter 3).

Under various global climate change scenarios, California is likely to see average annual temperatures rise by 4°F to 6°F in the next century, assuming actions are taken to reduce emissions of greenhouse gases. If no such changes are made, a "higher-emissions scenario" projects statewide temperature averages in California 7°F to 10.5°F higher. The range of figures comes from two models whose projections were summarized by the Union of Concerned Scientists in 2004. A theory suggests that high-elevation areas, such as the upper portions of the eastern Sierra Nevada, may warm more rapidly than regions as a whole.

The Department of Water Resources estimates that a 3ºF temperature increase could mean an 11% decrease in annual statewide water supply. Under the coolest climate change projections, there could be a loss of about 5 million acre-feet/year in snowpack water statewide. In the eastern Sierra Nevada, the snowpack would not be affected as much as in lower-elevation watersheds of the western slope because most of the heavy snowpack zone in the eastern Sierra Nevada watersheds is at higher elevations (above 8,500 feet) that would still receive mostly snow except under severe warming scenarios. There are also predictions of greater cloudiness in the Sierra Nevada under a warmer climate. However, clouds can either cool an area by blocking sunlight or keep it warm, functioning as a blanket in cold weather. There is uncertainty about how the effects of clouds might play out.

Under various scenarios, it is possible that the glaciers and permanent snowfields of the eastern Sierra Nevada will disappear by mid-century. For example, the Dana Glacier in the headwaters of Lee Vining Creek has already shrunk dramatically since the late 1800s. Chapter 3 contains a more in-depth analysis of possible localized climate change impacts for the region.

Topography, Geology, and Soils

Topography

The geology and land-forms of the Inyo-Mono IRWM planning area are difficult to characterize because of the diversity of the region. One of the few consistent traits is that the entire region is within the Great Basin – all watersheds have internal drainage with no natural outlets to an ocean. Therefore, there is a sense of hydrologic isolation of each of the component watersheds. This region lacks the natural hydrologic connectivity of IRWM groups organized by river basin. Again, it is useful to separate the region into an eastern Sierra Nevada zone and a northern Mojave Desert zone.

The eastern Sierra Nevada zone spans the border between two major geologic provinces: the

Sierra Nevada and the Basin and Range. The earth's crust in this region has been stretched apart, leaving a series of alternating mountain ranges and valleys. The mountain slopes tend to be quite steep with relatively little horizontal distance separating points differing in elevation by thousands of feet. The intervening valleys tend to be comparatively level and are composed mostly of materials eroded from the adjacent mountain slopes.

The crest of the Sierra Nevada is the western edge of the planning area and is largely above 10,000 feet in elevation. The crest includes much terrain above 12,000 feet and a few summits above 14,000 feet. The lowest parts of the crest (8,000 to 9,000 feet) are in the northwestern part of the West Walker River watershed, and the highest elevations are found west of Lone Pine and Big Pine. The steepest slopes in the region tend to be near the crest. At the extreme, small areas of the mountain front are vertical, and many areas along the mountains require technical climbing skills for travel. Slopes trend toward lower gradients with distance from the Sierra Nevada crest.

To the east of the Sierra Nevada are several broad valleys: (from north to south) Slinkard Valley (6,550 to 5,750 feet), Antelope Valley (5,600 to 5,000 feet), Bridgeport Valley (6,750 to 6,450 feet), Mono Valley and Mono Lake (6,700 to 6,380 feet), Long Valley (7,000 to 6,750 feet), Round Valley (4,900 to 4,400 feet), and Owens Valley (4,300 to 3,550 feet). There is a second group of intermontane valleys north of Owens Valley: Adobe, Benton, Hammil, and Chalfant.

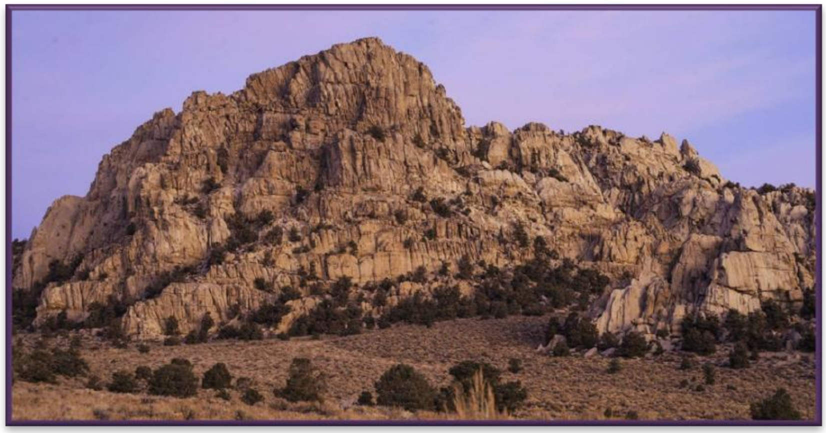
To the east of the main valleys, the terrain rises in a series of north-south oriented mountain ranges, which are the westernmost ranges of the Basin and Range geologic province. The larger of these ranges include the Sweetwater Mountains, Bodie Hills, Glass Mountains, and White-Inyo Mountains. These ranges also have steep topography and rise to between 10,000 and 14,000 feet.

The northern Mojave Desert zone is also part of the Basin and Range geologic province with steep mountain slopes and broad valleys between the ranges. The principal valleys are Saline Valley, Eureka Valley, Death Valley, Rose Valley, Panamint Valley, and Indian Wells Valley. The eastern slope of the southern Sierra Nevada defines the western extent of this southern zone. Among the main mountain ranges in this part of the Inyo-Mono planning area are the southern portion of the White-Inyo Mountains, Panamint Range, Grapevine Mountains, Funeral Mountains, Argus Range, Black Mountains, Greenwater Range, Slate Mountains, Owlshead Mountains, and Lava Mountains. Telescope Peak in the Panamint Range is the high point at 11,049 feet. Less than 20 miles to the east from Telescope Peak is the lowest topographic point in the nation at Badwater, about 282 feet below sea level.

Geology

The geology of each watershed influences many of the characteristics of water between its entry via precipitation and departure as streamflow or evaporation back into the atmosphere. There may also be a relatively small amount of water that leaves some watersheds as deep groundwater outflow -- obviously influenced by geology as well. Some of the important influences of geology with respect to hydrologic processes include serving as the parent material for soils, which in turn controls whether water remains on the surface or penetrates into the ground; storage and transport of water below the surface; chemical reactions and contributions of chemical substances to the water; potential for erosion and mass movement of soil and rocks; formation and control of stream channels; and substrate for vegetation, which removes much of the water stored in the soil.

Geology of the eastern Sierra Nevada zone is well described in a wide variety of sources (*e.g.,* Hill, 1975; Bailey, et al., 1976; Whitney, 1979; Lipshie, 1979 and 2001; Rinehart, 2003), and only a basic summary that relates to hydrology is included here. This zone occupies the junction of the Sierra Nevada and Basin and Range geologic provinces. The basic form of the main watersheds is a result of the uplift (and tilt to the west) of the Sierra Nevada relative to the valleys lying to the east of the range. The form of the upper Owens River watershed was further determined by the formation of the Long Valley caldera by a massive volcanic eruption about 760,000 years ago (Bailey, et al., 1976). Subsequent volcanic activity, earthquakes, erosion and deposition by glaciers, and stream channel processes have contributed to the present-day landscape. Glacial till from eight to twelve glacial advances covers much of the elevation zone between 6,500 and 8,000 feet near the main creeks from the Sierra Nevada.



A variety of rock types occupies the surface and the subsurface zones of the watersheds. Granitic rock of the Sierra Nevada batholith is exposed along the Sierra Nevada front in many places. Metamorphosed sedimentary and volcanic rocks are found on top of the granitic rock in places where erosion did not reach the granitic rock, such as Laurel, Convict, and McGee creeks. Volcanic rocks such as andesite, basalt, and the rhyolitic Bishop tuff (fused ash from the Long Valley caldera eruption with an average thickness of 500 feet [Gilbert, 1938]) are found above the older metamorphic and granitic rocks as well.

The northern Mojave Desert portion of the planning area is mostly composed of sedimentary and meta-sedimentary rock that formed from sediments deposited in shallow coastal waters and tidal flats. Volcanic activity and intrusive magma added basalts, rhyolites, and granitic rocks in localized areas. About 14 million years ago, the area started to be pulled apart by crustal movements, which resulted in a series of uplifted and tilted mountain ranges with valleys in between.

These various rock types have been further rearranged by the numerous faults in the area. The area beneath the town of Mammoth Lakes is particularly complex: interleaved layers of volcanic materials, glacial till, and stream deposits that are further stirred up by faulting. Volcanic processes have also formed many of the uplands throughout the eastern Sierra Nevada zone, such as the Bodie Hills, Anchorite Hills, Cowtrack Mountains, Glass Mountains, Mono Craters, Volcanic Tablelands, Crater Mountain, and Red Mountain.

The intermontane valleys initially formed as down-dropped fault blocks and subsequently filled with sediment transported from the adjacent mountain ranges. Sediment from glacial erosion, mass movements, surface processes, and channel erosion has filled the valleys to depths of hundreds of feet. The Owens Valley has some areas with up to 7,500 feet of alluvial fill. These sediment-filled depressions contain significant groundwater resources as water has filled the pore space between the sediment particles.

The magnitude 6 earthquake of May, 1980, in Long Valley prompted a great deal of local geological research. Dozens of scientific papers have provided a detailed understanding of the geologic history, structure, and activity of the Long Valley caldera (a roughly elliptical volcanic-tectonic depression measuring 18 miles from east to west and 10 miles from north to south). Some of this work is quite relevant to understanding groundwater storage, movement, chemistry, and interactions with surface flows.

The volcanic activity also creates a geothermal energy resource that is directly tied in with the groundwater system. The heat source for various hot springs, fumaroles, and hydrothermal alteration zones is presumed to originate from magma chambers at depths of a few thousand feet. Groundwater is warmed by heat rising from such areas and by water circulating from deep fractures. The presence of hot water at relatively shallow depths causes problems for municipal/domestic water production that seeks to avoid hot water with a high mineral content but provides the opportunity to extract heat for generation of electricity. The development of geothermal energy near the junction of U.S. Highway 395 and State Route 203 led to the creation of the Long Valley Hydrologic Advisory Committee, a technical group that monitors wells, springs, and streams down-gradient of the geothermal plant for signs of any changes that might be related to the geothermal development. Another large-scale geothermal generating facility is located at Coso, between Haiwee Reservoir and Little Lake.

Over geologic time, hot water circulation has contributed to concentrations of economically valuable minerals in many parts of the planning area. Prospecting for gold and silver occurred almost everywhere except in granitic rocks and lake sediments. Mines around Bodie were the most successful in the region. There were also substantial mining operations in Lundy Canyon, Mammoth Lakes, Onion Valley, Cerro Gordo, and Panamint City. Pine Creek, west of Bishop, was the location of one of the world’s largest tungsten mines for several decades.

During the Pleistocene geologic epoch (2.6 million to 12,000 years ago), the Inyo-Mono planning area had a much wetter climate and abundant runoff. The water formed a series of huge lakes that covered many of the intermontane valleys. Lake Russell filled the Mono Basin to a depth about 700 feet above the present Mono Lake. Water from Owens Lake overflowed to the south and formed Fossil Falls enroute to China Lake. The ancestral Amargosa River formed Lake Tecopa and filled much of Death Valley with Lake Manly. Panamint Lake and Searles Lake were also enormous bodies of water during the Pleistocene.

After the climate became much drier, the water evaporated and left vast mineral deposits behind on the lakebeds. Various salts, most importantly borax, were mined from these playa deposits during the late 1800s. Some operations, such as on the west shore of Owens Lake, continued until recent times.

Soils

Soils of the various watersheds throughout the planning area have formed from the underlying geologic parent material and consequently vary with the rock types as well as the localized moisture regime and weathering situation, biological influences, slope position and erosion potential, and time period for soil development. Most of the soils throughout the planning area tend to be shallow, coarse-textured, and poorly developed. The most common texture class is probably gravelly loam. Soils found on steeper soils tend to be shallow, loose, and unconsolidated, whereas soils found on relatively level areas in meadows and other alluvial deposits tend to be deeper, better developed, and less prone to erosion. Because many areas have very young parent materials, only a few hundred to a few thousand years in age, soils tend to be incompletely developed with minimal stratification.

Throughout the eastern Sierra Nevada zone, the soils at lower elevations are generally derived from granitic and volcanic parent material and are sandy loams and decomposed granite. Soil depth ranges from very shallow with lots of rocks to deep alluvium in the valleys (Thomas, 1984). At higher elevations, soil depths range from a few inches to 3 or 4 feet. Sandy loam is the most common texture, but rock content is commonly up to 35 percent, especially on steeper slopes. Water retention tends to be low and decreases when rock occupies a greater proportion of the volume (Thomas, 1984).

Soils on steeper mountain slopes are generally somewhat excessively to excessively drained, coarse-textured, and shallow. Soils that formed on the foothills are well to excessively drained, are shallow to moderately deep, and generally have coarse-textured surfaces with some having coarse-to-fine- textured subsoils. Soils developed on the high terraces are well to moderately well drained on nearly level to sloping terrain. Soils developed on low terraces are somewhat poorly to poorly drained on nearly level terrain. Most terrace soils lie above a heavy textured subsoil with a variety of surface textures. Soils on alluvial fans include well- to excessively-drained soils except where groundwater is present (Mono County Resource Conservation District, 1990).

Soils on floodplains are generally loamy and sandy in texture, and are deep to moderately deep with coarse-textured subsoils. Drainage is somewhat poor to very poor, and soils are eroded by past and present channels of the rivers. Soils formed in topographic depressions are generally clayey throughout and have high organic matter content. These soils also exhibit poor drainage conditions (Mono County Resource Conservation District, 1990). Nevertheless, soils on the valley flats are the best developed and most productive soils in the region. Such soils have allowed reasonably productive agriculture in the Antelope Valley, Bridgeport Valley, and Owens Valley for more than a century.

Within the once-proposed Sherwin Ski Area, which is somewhat representative of portions of the eastern slope of the Sierra Nevada, soils were limited to topographic benches, isolated pockets, and lower-angle swales (Inyo National Forest, 1988). On these low-angle portions of the terrain, soils up to 2 feet thick were noted, and organic layers of several inches depth were found in pocket meadows. Water holding capacity was generally less than 4 inches. Where thin soils were present on steeper slopes, they tended to be highly erodible, especially if disturbed (Inyo National Forest, 1988).

In the valleys once occupied by Pleistocene Lakes, as the water level dropped, salts accumulated in the more recent sediments, particularly on the gently sloping gradients. Soils derived from these sediments tend to have high salt content. In addition, salts and alkali affect many areas of poorly and very poorly drained soils on the floodplains, basins, and low terraces (Mono County Resource Conservation District, 1990).

The greatest potential for soil erosion occurs with sandy soils on steep slopes where water may flow over the surface and entrain soil particles. Areas where vegetation has been removed and soils mechanically compacted (*e.g,* roads, trails, construction sites, off-road vehicle routes) are much more subject to erosion than undisturbed areas. Wind erosion of exposed soils can be significant during high-wind events.

Upland and Riparian Vegetation

Upland Vegetation

Distribution and type of vegetation throughout the Inyo-Mono IRWM planning area are dependent on soils, moisture availability, air and soil temperature, and sunlight. Different vegetation communities tend to be associated with elevation zones because of the combination of environmental factors favoring different plants species. Slope aspect can also play a major role in plant distribution with greater moisture stress on south-facing slopes than on shaded north-facing slopes. The declining gradient in precipitation from west to east results in a rapid transition in vegetation -- from conifer forests in the Sierra Nevada to open woodlands in the hills to sagebrush scrub in the valleys just east of the Sierra Nevada (California Department of Water Resources, 1992). In the northern Mojave Desert zone, water availability also controls the composition and distribution of plant communities. Although trees can survive at elevations above 6,000 feet if sufficient moisture is available, most of the northern Mojave Desert zone is dominated by drought-tolerant shrubs.

At the Sierra Nevada crest on the western margin of the planning area, vegetation cover is sparse with the most wind-exposed locations nearly barren. In more protected locations, grasses, forbs, dwarf shrubs, and even a few whitebark pine (*Pinus albicaulis*) can be found. Moving downslope, the numbers of species and individual plants increase. In addition to the whitebark pine, mountain hemlock (*Tsuga mertensiana*) and western white pine (*Pinus monticola*) account for the tree species in the subalpine zone, which extends down to about 9,000 feet in the eastern Sierra Nevada watersheds. These trees merge into the red fir (*Abies magnifica*)-lodgepole pine (*Pinus contorta* ssp. *murrayana*) forest. The density of trees and the litter layer of accumulated needles are much greater here than among the scattered subalpine trees. The red fir-lodgepole pine forest merges into the Jeffrey pine (*Pinus jeffreyi*) forest at about 7,500 to 8,000 feet. Some white fir (*Abies concolor*) can be found among the Jeffrey pines. Western juniper (*Juniperus occidentalis* var. *occidentalis*) are also scattered in the east-side forests. Aspen (*Populus tremuloides*) clones are found where soil moisture is high and along creeks (USDA-Forest Service, 2004).

As in most other parts of the Sierra Nevada, decades of fire suppression have markedly changed the composition and density of the mixed conifer forest of the eastern Sierra Nevada. Dense stands of white fir and Jeffrey pine have taken over the former open stands of large Jeffrey pine that were maintained by relatively frequent low-intensity fires (Lucich, 2004). Conifers have also entered former aspen groves and reduced regeneration of aspen (Lucich, 2004).

At upper elevations in the eastern Sierra Nevada zone, shrub communities are comprised of tobacco brush(*Ceanothus velutinus*) and chokecherry (*Prunus emarginatus*). At lower elevations, the brush community is mostly sagebrush (*Artemesia tridentata*), bitterbrush (*Purshia tridentata*), mountain mahogany (*Cercocarpus ledifolius*) and snowberry (*Symphoricarpus albus*) (USDA-Forest Service, 1988).

The lower slopes of the Sierra Nevada (below 6,000 feet) are largely covered by a sagebrush (*Artemisia tridentata*) community, intermingled with meadows and some curlleaf mountain mahogany (*Cercocarpus ledifolius*). Typical species of the sagebrush community include bitterbrush (*Purshia tridentata*), rabbitbrush (*Ericameria* spp.), wheatgrass (*Agropyron* spp.), bluegrass (*Poa* spp.), wild-rye (*Elymus glaucus*), needle-grass (*Stipa* spp.), and June grass (*Koelaria cristata*) (Thomas, 1984).

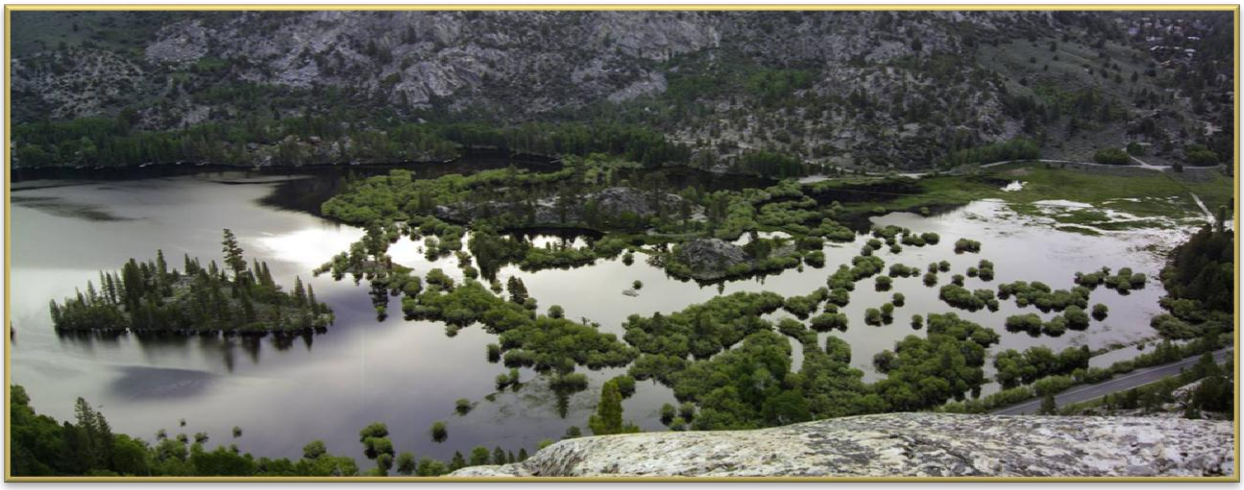
In the eastern ranges of the northern portion of the planning area, the main plant community is pinyon-juniper (*Pinus monophylla*, *Juniperus scopulorum*) woodland. Bitterbrush and sagebrush dominate the forest understory. The grass composition is similar to that of the lower-elevation Sierra Nevada front to the west (Thomas, 1984).

The vegetation at the lower elevations of the West Walker River basin (5,000 to 7,000 feet) has changed substantially since the 1860s from bunchgrass range to bitterbrush and sagebrush (*e.g.,* Thomas, 1984). Prior to the arrival of Euroamericans in the mid-19th century, portions of the West Walker River basin below and between the coniferous forest stands were primarily habitat for pronghorn and desert bighorn sheep. As overgrazing by thousands of domestic sheep during the late 1800s and early 1900s removed the bunchgrass, brush species became established. Consequently, the bighorn sheep and pronghorn left the area, and mule deer moved in, taking advantage of the browse species (Thomas, 1984). The native grasses, sedges, and rushes of the meadows were also converted to alfalfa and other forage species.

Plant communities of the northern Mojave Desert zone are completely different than those of the eastern Sierra Nevada zone because of the severely limited availability of water in the desert. Only plants able to survive high temperatures, low humidity, little soil water, and saline soils (in some places) are found in the northern Mojave Desert zone. The upper portions of the desert ranges receive several times more precipitation than the surrounding lowlands and are able to support pinyon-juniper woodlands above 6,000 to 7,000 feet (Tweed and Davis, 2003). Limber pine (*Pinus flexilis*) and bristlecone pine (*Pinus longaeva*) grow above 9,000 feet in the southern part of the White-Inyo Mountains and Panamint Mountains. Joshua trees (*Yucca brevifolia*) occur below the pinyon-juniper woodlands at about 4,000 to 6,000 feet (Ingram, 2008). At successively lower elevations and correspondingly drier sites, a wide variety of drought-tolerant shrubs are found. Common plants include sagebrush (*Artemisia tridentata*), rabbitbrush (*Ericameria nauseosus*), burrobush (*Ambrosia dumosa*), brittlebush (*Encelia farinosa*), creosote bush (*Larrea tridentata*), and mesquite (*Prosopis* spp.) (Tweed and Davis, 2003). Several cactus species (about 14) grow in the northern Mojave Desert zone and are well adapted to the arid conditions (Ingram, 2008). They tend to be more abundant in the eastern portion that has greater summer rainfall (Rowlands, 1995).

Riparian Areas and Wetlands

Riparian zones are the areas bordering streams, springs, and lakes that provide a transition from aquatic to terrestrial environments. In arid regions, such as the Inyo-Mono IRWM planning area, riparian areas and the water body they surround are the most ecologically important portions of a watershed. The presence of water allows much life to thrive close to the stream course that would otherwise not exist. As streams rise and fall, the lower parts of the riparian corridor may be inundated for days to weeks. Soil moisture is much higher within the riparian zone than farther up slope and is often saturated close to the stream. Plants within riparian corridors are adapted to the high soil moisture and occasional submergence. Depending on the nature of the soils, topography, and the stream, the riparian zone may be narrow or wide and have an abrupt or gradual transition to upland vegetation (Swanson, et al., 1982; Gregory, et al., 1991; Kattelmann and Embury, 1996).



Riparian areas are considered to be among the most ecologically valuable natural communities because they provide significantly greater water, food resources, habitat, and favorable microclimates than other parts of the landscape. The extra water alone leads to greater plant growth and diversity of species in riparian areas compared to other areas. The enhanced plant productivity, greater species richness, availability of water and prey, and cooler summer temperatures of riparian areas draws wildlife in greater numbers than in drier areas. Below the forest margin in the eastern Sierra Nevada, riparian areas are a dramatic change from the surrounding sagebrush scrub. In arid lands, streams, springs, and riparian zones are especially critical.

Streams and their adjacent riparian lands allow for the transport of water, sediment, food resources, seeds, and organic matter (Vannote, et al., 1980). Riparian corridors act as "highways" for plants and animals between natural communities that are stratified with elevation. The continuity of riparian corridors is one of their most important attributes. If the upstream-downstream connection is interrupted by a dam, road, or other development, the ecological value of the riparian system is greatly diminished.

In watersheds of the eastern Sierra Nevada, riparian corridors along the major creeks cross through several upland vegetation communities in just a few miles because of the steep topography. In the headwater areas, typical riparian vegetation includes lodgepole pine (*Pinus contorta* spp. *murrayana*), aspen (*Populus tremuloides*), mountain alder (*Alnus incana* spp. *tenuifolia*), currant (*Ribes* sp.), and willow (*Salix* sp.). Jeffrey pine (*Pinus jeffreyi*), black cottonwood (*Populus balsamifera* ssp. *trichocarpa*), and wild rose (*Rosa woodsii*) are present in some of the mid-elevation canyons. At elevations between the glacial moraines and the valley floor, water birch (*Betula occidentalis*), Fremont cottonwood (*Populus fremontii*), and other species of willow add to the mix (Howald, 2000a and 2000b).

Along the streams of the eastern Sierra Nevada, riparian environments offer critical resources for a large, though unknown, fraction of insect and other animal species. For some, the riparian zone is primary habitat. For other species, the riparian resources of water, food, higher humidity and cooler summer temperatures, shade, and cover are used on occasion. Insects are more abundant near streams and are an important food for fish, amphibians, birds, and mammals.

Open water and moist soils are both critical for amphibians. Almost all species of salamanders, frogs, and toads native to the Sierra Nevada spend much of their life cycles in riparian zones (Jennings, 1996). Birds tend to be far more numerous and diverse in riparian zones than in drier parts of the watershed. Most mammals at least visit riparian areas occasionally to take advantage of resources that are less available elsewhere in the watershed. The mammal most obviously dependent on the riparian zone is the beaver.

Riparian areas are fundamentally limited to the margins of streams, springs, creeks, and lakes. With their restricted width (generally tens of feet on either side of a stream, wider along flatter portions of the principal streams), riparian areas occupy very a small portion of the landscape. An evaluation of proposed hydroelectric projects in the eastern Sierra Nevada considered riparian zones to cover less than one percent of the surface area of their watersheds (Federal Energy Regulatory Commission, 1986).

Most of the riparian corridors at the higher-elevation portions of the Humboldt-Toiyabe and Inyo National Forests are relatively undisturbed (except by historical grazing), but many of the riparian areas in lower valleys have been changed by road construction, overgrazing, groundwater pumping, dams, water exports, and recreation. Some of the principal paved roads of the region follow streams for many miles and are often within the riparian zone. Forest roads are within the riparian zone in hundreds of places within the two National Forests of the eastern Sierra Nevada.

Although very important in their limited extent where they exist, there are few riparian areas within the northern Mojave Desert zone. Most are very short segments along channels downslope from springs and seeps that may only be tens to hundreds of feet in length. The Amargosa River canyon south of Tecopa is the best example of an extensive riparian area in the northern Mojave Desert zone. Due to the presence of cooler and wetter conditions and better soil, many washes support greater plant and animal diversity and productivity than the surrounding uplands, and the BLM has begun closing roads in washes in order to protect these biological resources.

Wetlands are areas that are flooded with water for enough of each year to determine how the soil develops and what types of plants and animals can live in that area. They are often called marshes, swamps, or bogs. The critical factor is that the soil is saturated with water for at least a portion of the year. This saturation of the soil leads to the development of particular soil types and favors plants that are adapted to soils lacking air in the pores for a portion of the year. The federal Clean Water Act defines the term wetlands as "those areas that are inundated or saturated by surface or ground water at a frequency and duration sufficient to support, and that under normal circumstances do support, a prevalence of vegetation typically adapted for life in saturated soil conditions."

General acceptance of the ecological values of wetlands has occurred relatively recently (National Research Council, 1995). Drainage and deliberate destruction of wetlands were widely accepted practices until the mid-1970s. California has lost a greater fraction of its wetlands than any other state. Only about 9 percent of the original wetlands (454,000 acres out of about 5 million acres) remain in California (National Research Council, 1992). The recognition of the importance of the small fraction remaining has led to a variety of regulatory efforts to minimize the further loss of wetlands. The relatively recent concept of wetlands as valuable to nature and the public at large has generated conflicts with individuals who own wetlands and do not see any personal benefit.

The largest areas of wetlands in the region are flood-irrigated lands in Antelope Valley, Little Antelope Valley, Bridgeport Valley, and Long Valley. Most of these areas would not be classified as wetlands without the artificial application of water for more than a century. Wetlands in much of Mono County have been inventoried and described in a project of the Lahontan Regional Water Quality Control Board and U.C. Santa Cruz in the 1990s (e.g., Curry, 1996).

The primary loss of wetlands in the upper Owens River watershed occurred with the filling of the Long Valley dam in 1940. A natural dam at the top of the Owens Gorge, caused by the relative rise of the Volcanic Tableland fault block (Lee, 1906), led to the low gradient of the Owens River through Long Valley and consequent conditions that favored wetlands along the river channel (Smeltzer and Kondolf, 1999). USGS topographic maps made circa 1913 during the studies by Charles H. Lee show more than 4,000 acres of wetlands within Long Valley (Smeltzer and Kondolf, 1999, esp. figure 20).

Within Inyo County, the primary wetlands occur in topographically flat portions of the Owens Valley where springs and seeps bring water to the surface. Wetlands that are important for wildlife are found at Fish Slough, north of Bishop, and near the Lower Owens River. Within the northern Mojave Desert zone, locally important wetlands include: Grimshaw Lake near Tecopa, Saratoga Springs in southern Death Valley, Saline Valley marshlands at foot of Inyo Mountains, Salt Creek and Cottonball Marsh north of Furnace Creek, and Warm Sulphur Springs at Ballarat in Panamint Valley. Several inventories and studies of springs have been conducted in Inyo County (e.g., King and Bredehoeft, 1999; Sada and Herbst, 2001; SGI, 2011; and Steinkampf and Werrell, 1998).

In addition to the obvious wetlands of the Owens Valley, there are several plant communities that transitional between wetland and upland vegetation types. Plants associated with these communities tend to produce roots that can be 4 to 7 feet long and can access a shallow water table where and when available. Such communities include alkali meadow, Nevada saltbush meadow, rabbitbrush meadow, desert sink scrub, greasewood scrub, and shadscale scrub (e.g., Groeneveld and Or, 1994; Elmore, et al., 2003).

Alpine and sub-alpine meadows also provide many ecosystem services for humans and wildlife yet have been damaged and degraded throughout much of the Sierra Nevada (e.g., Kattelmann and Embury, 1996; Stillwater Sciences, 2012; Viers, et al., 2013). These wetland ecosystems store and filter water that is diverted downstream for human uses; they provide high-quality habitat for invertebrate, birds, and mammals; and they can serve as indicators of past climatic and fire conditions as well as future changes in the climate. Mountain meadows are particularly critical habitat for birds, both for those species that are meadow-dependent and those that live in adjacent forests but obtain food and water from the meadows (Graber, 1996). Individual meadows throughout the mountain range have been inundated by reservoirs, intentionally drained and converted to other land uses, reduced by road construction, and altered by a variety of particular uses. However, a remarkably widespread suite of changes resulted from the range-wide overgrazing of the late 1800s. The removal of vegetation, compaction of meadow soils, and trampling of streambanks from vast numbers of sheep and cattle in the 19th century triggered a series of hydrologic and geomorphic consequences that have left a large fraction of Sierra Nevada meadows with deeply incised channels, lowered water tables, and changes in vegetation composition.

The majority of montane meadows in the Inyo-Mono planning region are found on the Inyo and Humboldt-Toiyabe National Forests. An inventory that was referenced in the Forest Plan of the Inyo National Forest (1998) indicated that 90 percent of the wet meadows on the Forest were damaged or threatened with damage by accelerated erosion. The majority of the meadow area on the Inyo National Forest is just west of the Inyo-Mono planning region on Kern Plateau, within the Southern Sierra planning region. Within the Inyo-Mono region portion of the Inyo National Forest, montane meadows can be found in the upper reaches of most watersheds tributary to the Owens River. Some of the larger meadows that have road access, such as Horseshoe Meadows and Snowcreek Meadow (Windy Flats on older maps), have a variety of impacts. Most of the smaller meadows at high elevations are relatively remote and are within the John Muir Wilderness Area. In the northern part of the Inyo-Mono planning region, montane meadows are mostly found on the Humboldt-Toiyabe National Forest and within the Hoover Wilderness Area. A few meadow areas are contained within "critical aquatic refuges", such as Kirkwood Lake, Koenig, Wolf Creek, Silver Creek, and Summit Meadow refuges (USDA-Forest Service, 2004). The largest montane meadows in the West Walker River watershed are Pickel Meadow and Leavitt Meadow, which were overgrazed in the 1800s and currently receive considerable recreation use because of their proximity to State Route 108.

Invasive Weeds

The term weed is typically used to describe any plant that is unwanted and grows and spreads aggressively. The term noxious weed describes an invasive unwanted non-native plant and refers to weeds that can infest large areas or cause economic and ecological damage to an area (USDA-Forest Service, 2004). The USDA-Natural Resources Conservation Service maintains a list of federally- and state-designated noxious weed species (http://plants.usda.gov/java/noxiousDriver#federal). In general, the Inyo-Mono region has thus far remained relatively free of major week infestations, but as visitations to the area increase, there will be an increased risk of significant alterations to native ecosystems. Already, as described below, tamarisk and cheatgrass pose major threats to the region.

At higher elevations, several invasive weeds have been identified, but a detailed description is beyond the scope of this plan. At lower elevations, invasive plants are even more aggressive and have caused widespread problems. Tamarisk or salt cedar (*Tamarix* spp.), a listed noxious weed, has invaded riparian zones, areas with high water tables, and water spreading basins below about 7,000 feet. It readily crowds out most beneficial riparian shrubs and trees and uses large amounts of water because of its ability to establish deep roots that extend below the water table adjacent to streams. In the Mono Basin, tamarisk is established at levels currently under control (due to an interagency effort) along the lower reaches of Rush and Lee Vining Creeks. Tamarisk has become well established along the lower Owens River and is being treated by the Inyo County Water Department and Los Angeles Department of Water and Power. In the northern Mojave Desert zone, tamarisk removes much of the scarce water from springs and ephemeral stream channels that would otherwise benefit many plants and animals.

Perennial pepperweed (*Lepidium latifolium*) is of increasing concern in the region because of tendency to contribute to erosion of streambanks and the sides of ditches and canals, its tendency to develop monocultures, as well as its aggressive invasive nature and resistance to control. As another example, cheatgrass (*Bromus tectorum*) has been found to produce between 400 and 3400 lbs of vegetative matter per acre (depending on irrigation, soil, etc.), reduces soil moisture several inches below soil surfaces before native plants begin germinating, tends to increase fire frequency and severity, and is affecting pollinator populations and predator-prey relationships on the east slopes of the Sierra Nevada. Other invasive plants, such as woolly mullein (*Verbascum thapsus*), Russian thistle (*Salsola* sp.), Russian olive (*Elaeagnus angustifolia*), and knapweed (*Centaurea* spp.) also have serious implications for terrestrial and aquatic ecosystems. Several other problematic species are targeted by property owners, agencies, and a group formed to combat invasive weeds.

Most of the eastern Sierra Nevada zone of the Inyo-Mono IRWM planning area is covered by the Eastern Sierra Weed Management Area, a consortium of land management agencies and other entities formed in 1998. The mission of this group is the control and eradication of noxious weeds through integrated management activities. Members of the group include Inyo/Mono Counties' Agricultural Commissioner's Office, Inyo County Water Department, California Department of Food and Agriculture, Los Angeles Department of Water and Power, Bureau of Land Management Bishop Field Office, Bureau of Land Management Desert District, Inyo National Forest, Humboldt-Toiyabe National Forest, Inyo/Mono Resource Conservation District, Inyo/Mono Counties' Cattleman's Association, Natural Resources Conservation Service, California Department of Forestry and Fire Protection, California Department of Transportation District 9, Bishop Paiute Tribe Environmental Office, and California Department of Parks and Recreation.

Role of Wildfire

Wildfires are a major watershed management issue as well as natural hazard within the eastern Sierra Nevada zone of the Inyo-Mono IRWM planning area. Wildfires are not much of a concern (except in localized areas and under unusual conditions) within the northern Mojave Desert zone because of the sparse vegetation.

Fire is a natural disturbance feature of the landscape. Prior to the 20th century, the primary cause of fire was lightning, coinciding with summer thunderstorms. When ignited at higher elevations, the fires were typically not large. Lower elevations experience fewer lightning ignitions, but the shrublands have the potential to burn more extensively, and have in the past. Fire suppression policies were instituted in the early days of the National Forest System. With the near absence of wildfire in the past century, fuel loads in forest and shrublands far exceed natural levels. Therefore, modern fires are likely to be both intense and extensive.

Analyses of tree stumps and cores have suggested that pre-1900 intervals between wildfires were highly variable in the upper Owens River watershed. Before active fire suppression, fires occurred in the Jeffrey pine and mixed conifer stands about every 10 to 20 years on the average, and in red fir stands about every 30 years on the average (Millar, et al., 1996). Wildfires appear to have been low intensity in both pine and fir forests; however, the structure of some red fir stands indicates that stand-replacing fires occurred. The studies of fire history show that the size, frequency, and distribution of fires changed markedly with the beginning of suppression (Millar, et al., 1996).

In the high-elevation subalpine zone, wildfires are uncommon, infrequent, and usually limited to only a few trees. No large historical fires have been documented at elevations over 8,000 feet in the eastern Sierra Nevada zone. Fires intensities tend to be low, and large fires rarely develop. The subalpine zone tends to be cooler and wetter than areas at lower elevation. Forest structure is probably the closest to reference conditions in the subalpine zone because of the scarcity of fire. Most of the late successional forest stands are found at these higher elevations (USDA-Forest Service, 2004).

Fish and Wildlife

Fish, particularly trout, are a highly valued recreational resource of the streams of the eastern Sierra Nevada. Much of the tourism economy of the area is dependent on fishing. The streams and lakes of the region have hundreds of thousands of angler-days of use each season. Introduced in the late 1800s, trout have become thoroughly integrated into the aquatic ecology of eastern Sierra Nevada watersheds, often at the expense of native fish and amphibians. The extent and numbers of non-native trout increased dramatically when aerial stocking of trout became widespread in the 1950s. Before the artificial stocking, most waters in the eastern Sierra Nevada did not contain trout, except for a few creeks that contained native Lahontan cutthroat trout (*Oncorhynchus clarki henshawi*) (Milliron, et al., 2004). Many strains of rainbow trout (*Oncorhynchus mykiss*), brown trout (*Salmo trutta*), and brook trout (*Salvelinus fontinalis*) have been planted in lakes and tributaries of the main rivers, and many of these trout have successfully spawned, producing “wild trout” progeny. The term “wild trout” is distinct from “native trout,” which refers to trout that existed in streams prior to European settlement and have a defined natural range without human intervention (Milliron, et al., 2004).

The Lahontan cutthroat trout (*Oncorhyncus clarki henshawi*) is the prominent species of native fish in the Walker River basin. The original range of the Lahontan cutthroat trout has been reduced more than 90 percent by changes in streamflows, channel conditions, and overfishing (Knapp, 1996). Predation by, competition with, and hybridization with introduced trout have also greatly impacted the remaining groups of these fish (Gerstung, 1988). As the once huge population in Walker Lake has declined drastically with increasing salinity, efforts have begun to ensure survival of the species in streams of the upper watershed. When only a few isolated populations could be found, the Lahontan cutthroat trout was listed as endangered under the Endangered Species Act in 1970 and then reclassified as threatened in 1975. The fragmentation of habitat leading to the isolation of small groups of fish is a primary concern.

Native fishes of the Long Valley streams include Owens sucker (*Catostomus fumeiventris*), Owens tui chub (*Gila bicolor snyderi*), toikona tui chub (*Gila bicolor* subspecies), and speckled dace (*Rhynichthys osculus*) (Hubbs and Miller, 1948; Miller, 1973, Chen et al., 2007). The U.S. Fish and Wildlife Service (1998) recommended four “Conservation Areas” within Long Valley to help with recovery of Owens tui chub and Long Valley speckled dace: Little Hot Creek, Whitmore, Little Alkali, and Hot Creek. Within the Owens Valley, the Owens pupfish (*Cyprinodon radiosus*) was the primary native fish. However, the species was reduced to just two locations by 1934 and was thought to be extinct by 1948 (Pister, 1995). After a small population of surviving Owens pupfish was found in 1956, the California Department of Fish and Game, LADWP, and BLM cooperated in creating refuges for the species in the Fish Slough area north of Bishop. Introduced non-native fish, such as largemouth bass (*Micropterus salmoides*), remain a threat to the continued survival of the pupfish.

Fish introductions to the Owens River basin began in the late 1800s with Lahontan cutthroat trout from the Walker River and golden trout from the Kern River. Rainbow, brown, and eastern brook trout from hatcheries in other parts of California were first introduced in about 1900 (Pister, 1995). The Mount Whitney State Fish Hatchery, built in 1917, lead to significant fish rearing and stocking programs in waters of the eastern Sierra Nevada.

The upper Owens River through lower Long Valley, before the reservoir started filling in 1941, was regarded as a "superb stream fishery". The subsequent lake is also a highly productive fishery. The growth rates of rainbow trout and brown trout in Crowley Lake are among the highest ever recorded for a resident trout population in a mountain environment (Von Geldren, 1989). Crowley Lake's high productivity results in trout that gain from three to 40 times their stocked weight before harvest (Milliron, 1997).

In the northern Mojave Desert zone, there are a few isolated populations of pupfish that have remained after Lake Manly dried up. Four species and ten subspecies of pupfish are found in streams, springs, and wetlands of the northern Mojave (Tweed and Davis, 2003). Within California, these fish are located in the Amargosa River, Saratoga Springs, Salt Creek, and

Cottonball Marsh.

Amphibians are assumed to be scattered throughout the Sierra Nevada watersheds, but have been depleted by introduced trout (e.g., Knapp and Matthews, 2000). The larger populations are found in waters without fish. Amphibian populations are also assumed to be declining in the eastern Sierra Nevada as is the case in most of the Sierra Nevada due to disease and predation (e.g., Jennings, 1996). In past decades, anecdotal accounts suggested that frogs and toads were very common, abundant, and widespread. During the 1980s, biologists began to note that amphibians were becoming relatively uncommon and detected diseases and deformities that have not been noticed or at least not widely described in the past. A recently identified disease, chytridiomycosis, caused by a fungal pathogen, appears to be spreading at an alarming rate and greatly reducing population size of some amphibian species (Rachowitz, et al., 2006). The principal amphibians of the eastern Sierra Nevada watersheds are Yosemite toad (*Bufo canorus*), mountain yellow-legged frog (*Rana muscosa*), and Pacific tree frog (*Hyla regilla*). Salamanders--including the poorly described Kern Plateau slender salamander (*Batrachoseps robustus,* imperiled) and a southern species of web-toed salamander (*Hydomantes platycephalus)*--are present in some areas as well. The Humboldt-Toiyabe National Forest has established several "critical aquatic refuges" to promote recovery of threatened amphibians. The Kirkwood Lake refuge was established for the mountain yellow-legged frog. It covers 840 acres at the higher elevations of the West Walker River watershed. Surveys of the refuge in 2000 found a total population of more than 10,000 frogs, among the heaviest concentrations in the Sierra Nevada. In addition to these frogs, Yosemite toad larvae were also found in this refuge in the 2000 survey. The Koenig Lake refuge was established for Yosemite toads. It includes 2000 acres in the Latopie, Koenig, and Leavitt lakes subwatersheds. Recent surveys found Yosemite toad tadpoles in the wetlands surrounding Koenig Lake and in unmapped ponds between Koenig and Latopie lakes (USDA-Forest Service, 2004). At the lower elevations surrounding Mono Lake and in the Owens Valley, Great Basin spadefoot toads are common.

The Sierra Nevada yellow-legged frog and Northern Distinct Population Segment of the mountain yellow-legged frog were listed as endangered by the U.S. Fish and Wildlife Service in June 2014. The Yosemite toad was listed as threatened at the same time. During the decade prior to the actual listings under the Endangered Species Act, there was considerable concern and controversy within Inyo and Mono counties about the potential for the listings. The rumor mill generated fears that grazing, pack stock use, and recreational fishing could be severely constrained in any area deemed critical habitat for the amphibians. Although such actions now seem unlikely, recovery plans for these species are yet to be developed.

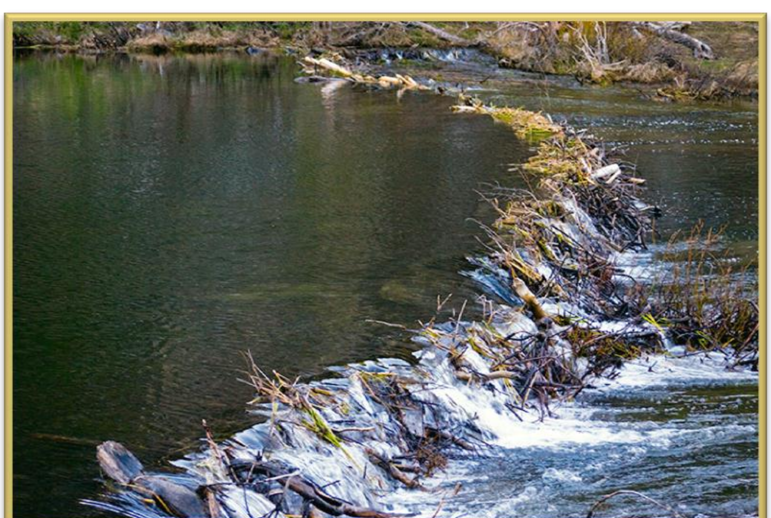
A few species of amphibians and reptiles eke out an existence at isolated springs and seeps in more arid reaches of the project area. These include the Panamint alligator lizard (*Elgaria panamintina*, threatened and in decline), the black toad (*Anaxyrus exsul*), threatened but apparently stable), the Inyo slender salamander (*Batrachoseps campi*, a California species of special concern), the Great Basin spadefoot toad (*Spea intermontana*), the red-spotted toad (*Bufo punctatus*), and the western toad (*Bufo boreas*).

Terrestrial Wildlife

In a watershed context, the animals that have the greatest impact on watershed processes are those largely unseen and unappreciated creatures that live below the soil surface and perform an immense amount of work in the soil. The activities of burrowing mammals, reptiles, insects, worms, and amphibians process organic matter and alter the physical structure of the upper part of the soil. Animals in the soil can have a huge effect on the pore space and structure of the soil and, consequently, on the infiltration capacity and water storage capacity of the soil. Human activities that impact soil organisms, such as excavation, compaction, vegetation removal, and pollution, can have secondary impacts on the water relations of the soil.

Animals that are traditionally considered as "wildlife" are primarily of interest in the watershed context with respect to riparian habitat. The eastern Sierra Nevada does not have any wildlife species with either the behavior (*e.g.,* bison) or numbers (*e.g.*, elk in Rocky Mountain National Park) to make substantial changes in soil properties, vegetation, or stream conditions to alter hydrologic response of the watershed. Nevertheless, all native species have ecological roles, and one could imagine some hydrologic consequences if the population of some species were drastically changed. Fish and wildlife habitat of the upper elevations of the Inyo-Mono IRWM planning area tends to be in excellent condition while the lower portion, below about 7,000 feet elevation, tends to be in less satisfactory condition (Inyo National Forest, 1988).

Most wildlife species are dependent on the riparian zone, at least occasionally, for water, food, or shelter. Changes in riparian and associated wetland vegetation composition, density, and continuity can have serious impacts on wildlife. In most of the Inyo-Mono IRWM planning area, the stream corridors are critically important because of the lack of water elsewhere in the landscape. Wildlife dependent on the creek water and riparian habitat include mule deer (*Odocoileus hemionus*), white-tailed jackrabbits (*Lepus townsendii*), Nuttall's cottontail (*Sylvilagus nuttallii)*, montane vole (*Microtus montanus*), mink (*Mustela vison*), Yosemite toad, and mountain yellow-legged frog. Many birds also use eastern Sierra Nevada riparian habitat, including mourning dove (*Zenaida macroura*), Sooty grouse (*Dendragapus fuliginosus*), band-tailed pigeon (*Columba fasciata*), red-winged blackbird (*Agelaius phoeniceus*), song sparrow (*Melospiza melodia*), northern goshawk (*Accipiter gentilis*), osprey (*Pandion haliaetus*), and red-tailed hawk (*Buteo jamicensus)*. Kestrels (*Falco sparverius*), ravens (*Corvus corax*), goshawks (*Accipter gentilis*), red-tailed hawks (*Buteo jamaicensis*), prairie falcons (*Falco mexicanus*), and golden eagles (*Aquila chrysaetos*) also utilize riparian zones as part of their habitat.



Of the several wildlife species that use eastern Sierra Nevada riparian habitats for foraging, nesting, or cover, some are threatened or endangered or are of special concern. These species include the willow flycatcher (*Empidonax traillii*), greater sage grouse (*Centrocercus urophasianus*), peregrine falcon (*Falco peregrinus*), bald eagle (*Haliaeetus leucocephalus*), osprey (*Pandion haliaetus*), yellow warbler (*Dendronica petechia*), mountain beaver (*Aplodontia rufa*), and Inyo shrew (*Sorex tenellus*) (USDA Forest Service, 1989; California Department of Fish and Game, 1990). Long-distance migrant birds depend on riparian habitats as they travel through the arid Great Basin. The greater sage grouse within Mono County is currently the subject of considerable attention in a Nevada-California effort to avoid the species being listed under the Endangered Species Act (e.g., Casazza, et al., 2009). The Mojave population of desert tortoise is listed as threatened under the federal endangered species act, and the Fish and Wildlife Service updated its recovery plan for the population in 2011 (US Fish and Wildlife Service, 2011).

One species with direct hydrologic impacts is the beaver (*Castor canadensis*), with their dam-building behavior. Beaver were not known to exist in the Owens and Long valleys when EuroAmericans began settling the area. After World War II, there was a debate within the California Department of Fish and Game about the benefits and risks of introducing beaver. Within the West Walker River watershed, beaver were present along several streams in 1967: Little Walker River, West Walker River, Mill Creek, and Lost Cannon Creek (memo in CDFG files in Bishop office, no date). Beaver were introduced along Mill Creek in the Mono Basin by the Department of Fish and Game in the 1950s. The population thrives above Lundy Reservoir for nearly the entire length of upper Lundy Canyon and in recent years has been spreading to nearby creeks, including Wilson Creek, DeChambeau Creek, and Lee Vining Creek.

Mule deer (*Odocoileus hemionus*) are the most prominent big game species of the eastern Sierra Nevada. The West Walker deer herd is a significant wildlife resource within the basin and affects many land management decisions. The Round Valley deer herd is of similar importance between Bishop and Mammoth Lakes.

Social and Cultural Characteristics

Human History

As in most of California, the history of native peoples, Euro-American settlement, early land use, and water development has established the current socio-economic conditions in the Inyo-Mono planning region. Unlike most of California, the earlier history has had much greater relative influence than more recent events. Land allocations to federal land management agencies, the City of Los Angeles, and a relatively small number of large ranches were largely completed well before World War Two. The very small proportion of private land within the region has limited development, land-use change, and population growth in recent decades. For example, between 1970 and 2010, Inyo County's population grew by only 19 percent, compared to California's growth rate of 87 percent over that 40-year span. With the limited private land base and presumably fixed allocations of land, comparatively little growth or land-use change is anticipated within the Inyo-Mono planning region over a planning period of the next twenty years.

Pre-history

Native Americans of the Paiute and Washoe tribes lived in the Walker River basin for at least several hundred years. The tribes established settlements in valley bottoms along rivers and lakes. Smaller temporary settlements and campsites were occupied at higher elevations during warmer months and while on food gathering and trading forays. The Miwok from west central California also used the Sonora Pass area and crossed over Tioga Pass (USDA-Forest Service, 2004).

The North Mono Basin is the ancestral home to the Mono Lake Paiute (or Kuzedika Paiute) Indians and has been occupied continuously for the last 10,000 years. The population and geographical distribution of the native people of the Mono Basin is not known, but they survived upon the natural resources of the basin and traded surpluses with people to the west. After Euro-Americans arrived in the 1860s, logging deprived the Kudezika Paiute of pine nuts from pinyon pines and caterpillars from Jeffrey pines; sheep grazing damaged the meadows that were the source of seeds, roots, and bulbs; and hunting reduced the pronghorn, bighorn sheep, and sage grouse (Gaines, 1989).

The upper Owens River watershed was probably mostly occupied in the summer months by the Paiute people who could find more favorable year-round conditions in the Owens Valley or to the east. The persistent snowpack and low temperatures were likely to keep Native Americans out of the area during winter and early spring. However, there is some evidence for year-round occupancy of Long Valley, at least in the 1800s (Burton and Farrell, 1992). Presumably, there were good hunting opportunities in the watershed during the snow-free part of the year, and people from adjoining areas lived at the higher elevations during the summer. The Glass Mountains and Obsidian Dome provided high-quality obsidian for projectile points and tools. Volcanism, including ash falls as recently as 660 and 1,210 years ago (Wood, 1977), may have affected the vegetation, wildlife, and water of the upper Owens River watershed enough to limit Native American use of the area for periods of time (Hall, 1984).

Paiute people had villages near Owens Lake and presumably farther north in the Owens Valley for centuries. There is evidence of dams and irrigation canals on Bishop and Big Pine Creeks dating back about 1,000 years. At least two square miles of bottomlands were irrigated by these canals to enhance the growth of native vegetation (Steward, 1934; Lawton, et al., 1976).

In the northern Mojave desert zone, semi-nomadic people had camps near the receding Lake Manly for at least 10,000 years (Tweed and Davis, 2003). There is little archaeological evidence of habitation between 7,500 and 4,500 years ago when the region dried out. After the climate moderated somewhat about 4,500 years ago, the archaeological record indicates occupation of the area resumed. The Kawaiisu people lived in the Indian Wells and Panamint valleys and the foothills of the southeastern Sierra Nevada. Southern Paiutes lived in the vicinity of present-day Tecopa, and Western Shoshone lived in the most arid parts of the area, such as Saline and Death valleys. Villages near water sources were estimated to be occupied by about 50 to 60 people, and total population of the northern Mojave desert region was probably less than 1,000 people (Tweed and Davis, 2003).

1820-1855

Trappers, including Jedediah Smith and Joseph Walker, apparently crossed the lower Walker River basin in 1827 and 1833. The first Euro-Americans known to have visited the West Walker River basin were in the Bartelson-Bidwell party, who were the first overland emigrants to California. This group came through Antelope Valley in October 1841, and struggled over the Sierra Nevada somewhere north of Sonora Pass. The earliest exploration of the upper Owens River watershed by Euro-Americans is uncertain. LeRoy Vining began prospecting in the Mono Basin in 1852 or 1853.

In 1834, Joseph Walker descended into Indian Wells Valley from Walker Pass and may have entered the southern portion of Owens Valley. He was back in 1843, passing Owens Lake with a party of 50 emigrants before ascending Walker Pass (Tweed and Davis, 2003). John C. Fremont traveled through the Owens Valley in October of 1845 and named the lake, river, and valley for one of his guides, Richard Owens, who was not present during that part of the expedition (Chalfant, 1933).

Traveling west from the vicinity of present-day Las Vegas, a party led by Antonio Armijo followed part of the Amargosa River and passed through the southern end of Death Valley during the winter of 1829-30 (Tweed and Davis, 2003). This route later became known as the “Spanish Trail”. In the autumn and winter of 1849, several parties of emigrants ventured into Death Valley and experienced great hardships. Not all members survived – leading to the eventual name of the valley.

1855-1900

Antelope Valley was settled in the late 1850s and began to produce hay for Carson City and Virginia City (Mono County Resource Conservation District, 1990). Irrigation ditches were soon constructed to expand the land under cultivation. In addition to hay fields and pastures, farmers in the valley grew beans, melons, corn, tomatoes, and berries and started orchards that produced apples, peaches, and plums.

Settlers moved into the Owens Valley during the 1850s. During the winter of 1861-62, the greatest floods of the historical period were observed throughout the Sierra Nevada. Although the upper Owens River watershed was probably unoccupied at the time, persistent rainfall intermixed with snow led to extreme flows in the streams entering the Owens Valley. At the peak of the floods, the Owens River was estimated to be one-fourth to one-half mile wide. The harsh winter and inundation of the Owens Valley led to violent conflicts over food between Paiutes and early white settlers (Chalfant, 1933).

Although gold was discovered near Bodie in 1859 and in Aurora in 1861, these mining areas did not take off until the late 1860s and early 1870s. The mining booms drew lots of travelers through the West Walker River and East Walker River watersheds and produced heavy demand for agricultural products from the rapidly growing farms of the Antelope and Bridgeport Valleys. N.B. Hunewill established a sawmill in Buckeye Canyon to supply lumber for Bodie. Sheep herding expanded in the uplands in response to the demand from the mining towns, and continued in large numbers into the early 1900s.

In the Mono Basin, prospecting led to towns in Lundy Canyon, upper Lee Vining Creek, and Rattlesnake Gulch. Farms and ranches in the basin supplied food to these gold-mining communities. Irrigation ditches were developed at that time to bring water from creeks to pastures and farm fields. LeRoy Vining operated a sawmill in Lee Vining canyon in the 1860s.

A group of prospectors continuing the search for the "Lost Cement Mine" in 1877 found a rich gold-silver vein in "Mineral Hill" or "Red Mountain" just east of Lake Mary (DeDecker, 1966). They called it the "Mammoth Vein" and organized the Lake mining district. Word of the new strike spread quickly, and miners rushed to the area. Mining camps were built nearby, including Mammoth City, Pine City, Mill City, and Mineral Park. The combined population in 1879 was thought to exceed 1,500 (DeDecker, 1966). A dam was constructed at Twin Lakes to supply hydro-mechanical power. The mining boom led to construction of a wagon road from Benton, a toll road up the Sherwin Grade from Bishop, and a toll trail from Oakhurst to supply beef cattle (DeDecker, 1966).

During the mining boom, the Owens Valley became home to farmers and ranchers and had a population of several thousand people by the turn of the century (Irwin, 1991). Some Owens Valley ranchers drove cattle and sheep into the highlands of Long Valley and the upper Owens River area for summer and fall grazing in the 1880s (Burton and Farrell, 1992). There are no records of the extent or intensity of grazing for the first few decades. When the Inyo National Forest took over administration of the forested federal lands from the Sierra Timber Reserve in 1908, one of the first tasks was to control overgrazing (Millar, et al., 1996).

The mining town of Kearsarge in Onion Valley was destroyed by avalanches in 1864. Silver was discovered in 1865 at Cerro Gordo, east of Owens Lake. In 1872, the strongest earthquake in California’s history devastated Lone Pine, which had about 250 residents at the time.

During the 1880s, borax and other minerals were mined from the playas at Searles, Panamint, Amargosa, and Death Valleys. In 1893, the U.S. Department of Agriculture’s Death Valley Expedition published its report on the biological resources of Death Valley and adjacent areas.

1900-1930

Many of the farms and ranches of Antelope Valley were consolidated in the 1880s by cattle baron Thomas B. Rickey. By the turn of the century, Rickey's operations were using enough water that downstream ranchers in Smith and Mason valleys believed that their water rights were being infringed upon. In 1899, work began on Topaz Reservoir and was later completed by downstream water interests that formed the Walker River Irrigation District in 1919. Water storage began in 1921, and by May 1924, about 30,000 AF of water were stored in Topaz Reservoir (California Department of Water Resources, 1992).

As more people in southern California accumulated wealth and leisure time in the early 1900s, the eastern Sierra Nevada, including the Mammoth Lakes area, became a destination for summer recreation. An automobile trip from Los Angeles required about two and a half days in 1914. A paved road along the eastern escarpment of the Sierra Nevada (close to the present route of U.S. Highway 395) would not be completed until 1931 (Irwin, 1991).

Large-scale development of the water of the Owens River began in 1903 when the U.S. Reclamation Service began a study of water resources in the eastern Sierra Nevada. Establishment of the Inyo National Forest was apparently linked to potential water development (Martin, 1992). Watershed protection was proclaimed as the reason for creating the Inyo National Forest by President Theodore Roosevelt in May, 1907. After the lands were surveyed in 1905, one of the Forest Service employees wrote: "This addition will protect and regulate the water flow of the Owens River and its tributaries" and [the lands] "were set aside to protect the Owens River watershed, to protect the water supply of the City of Los Angeles" (Ayres, 1906; quoted in Martin, 1992). The City of Los Angeles began acquiring land and water rights in the Owens Valley as well as performing initial engineering work for an aqueduct and storage facilities in the early 1900s. Construction began in 1908, and water was flowing through the completed aqueduct in 1913. During a dry period in the 1920s and early 1930s, Los Angeles completed approximately 170 new wells in the Owens Valley to supplement water exports via the first aqueduct using groundwater from underlying aquifers in the Owens Valley.

As railroads and roads expanded through the Northern Mojave Desert, development of the region’s mineral wealth became more feasible. Lead and gypsum were mined near Tecopa. Several evaporite minerals were mined from Searles Lake. Salt was brought out of Saline valley via an aerial tramway. Talc was mined in the Amargosa Valley, Panamint Valley, and elsewhere in the region. Production of borax from Death Valley resumed after 1910 (Tweed and Davis, 2003).

1930-Present

The capacity of Topaz Reservoir was increased to about 60,000 acre-feet in 1937. The Marine Corps Mountain Warfare Training Center in Pickel Meadow was established in 1951.

Construction of the Mono Craters Tunnel and stream diversion works began in 1934, Grant Lake dam was enlarged in 1940, and water export from the Mono Basin began in 1941. Export capacity was increased in 1970 with completion of the second barrel of the Owens Valley aqueduct to Los Angeles. Several lawsuits regarding Mono Lake and tributary streams were settled in the 1980s, resulting in minimum flows for Rush and Lee Vining Creeks. In 1994, the

State Water Resources Control Board issued decision D-1631, amending LADWP's water diversion licenses.

In 1932, the Los Angeles Department of Water and Power purchased Fred Eaton's ranch in Long Valley and began construction of the Long Valley dam. In the following years, the Department purchased other properties in Long Valley to secure water rights of the tributaries to the Owens River. After water from the Mono Basin began to flow through the tunnel in 1941, the upper Owens River served as a canal with extra flows averaging 50,000-100,000 acre-feet per year for the next 50 years. The Pleasant Valley Dam was constructed in 1957.

In 1970, Los Angeles completed its second aqueduct and filled it with 1) increased groundwater exports from the Owens Valley; 2) increased surface water exports from the Owens Valley (obtained from reductions in irrigation water previously supplied to Owens Valley ranchers), and 3) increased surface water diversions from the Mono Basin. The consequent groundwater pumping impacts to Owens Valley springs and ecosystems stimulated a series of legal actions that resulted in a joint groundwater management agreement for Inyo County in 1991, the partial rewatering of 62 miles of the lower Owens River in 2006, and several other environmental mitigation projects, some of which have not yet been completed. By the 1930s, Owens Lake was completely dry due to diversions.

Death Valley National Monument was established in 1933 and enlarged in 1937. Tourism gradually increased as roads were improved and facilities were built, initially with labor from the Civilian Conservation Corps. In 1994, Congress enacted the California Desert Protection Act, which changed the designation from Monument to Park and added 1.3 million acres. Death Valley National Park is now the largest of the national parks in the contiguous U.S. The California Desert Protection Act also directed that a study be conducted to locate a reservation for the Timbisha Shoshone tribe. In 2000, enactment of the Timbisha Land Act established a 300-acre reservation at Furnace Creek (Tweed and Davis, 2003). During World War Two, the U.S. Navy established the Inyo-Kern Naval Ordinance Test Station (now called the Naval Air Weapons Station at China Lake) in the Indian Wells Valley. The facility and adjacent city of Ridgecrest is by far the largest population center in the Inyo-Mono IRWMP planning area.

Land Use

As automobiles became more common, the driving public pushed for more roads and those roads, in turn, influenced land use. Growth accelerated after World War II and winter recreation began to be a potent economic force. The first chairlift at Mammoth Mountain Ski Area was installed in 1955. Twenty-five lifts were in service by the mid-1980s, and snowmaking equipment began to be installed in the early 1990s. In 2004, the resort recorded 1.5 million skier-days, second only to Vail ski area in Colorado.

The Town of Mammoth Lakes began to grow significantly in the late 1960s. In 1971, the Inyo National Forest plan stated that Mammoth Lakes was the "fastest growing community in the country" (Millar et al., 1996). The 1990 census reported a population for the town of 4,785. Another period of dramatic growth occurred in the late 1990s, with census results of 7,100 in 2000 and 8,200 in 2010.

The Inyo-Mono IRWM planning area is largely in public ownership for conservation and management of natural resources. Only about 1.7 percent of Inyo County is in private ownership, and there is only slightly more private land in Mono County. Outdoor recreation on public lands by visitors from outside the region drives the local economies. Agriculture is the dominant land use on private property in the area. About 71,000 acres of Mono County and 22,000 acres of Inyo County are under irrigation for alfalfa, miscellaneous hay, and irrigated pasture. Agricultural activities also occur on public land in the planning area. Land is also dedicated to military uses at the Naval Air Weapons Station at China Lake and Mountain Warfare Training Center east of Sonora Pass.

Recreation is a major land use and dominant economic force throughout the Inyo-Mono IRWM planning area because of the scenic beauty and high proportion of public land. The Inyo National Forest receives about ten million visitor-days of use per year. Recreation is also popular on lands of the Humboldt-Toiyabe National Forest, Bureau of Land Management, Death Valley National Park, and Los Angeles Department of Water and Power.

The Mammoth Mountain Ski Area is potentially the largest single source of sediment within the upper Owens River watershed. Mammoth Mountain has more than 30 ski lifts on a permit area of 3,200 acres with a design capacity of 19,000 skiers at one time. Ski areas have an inherent conflict between providing good skiing conditions with shallow snow and maintaining enough vegetation to minimize erosion. The steep slopes of ski runs also allow flowing water to apply sufficient force to readily dislodge soil particles. Besides these fundamental issues common to all ski areas, the pumice and poorly developed soils on Mammoth Mountain are prone to erosion once disturbed and stripped of vegetation. The ski area has an active erosion control program and has successfully established grasses on many of the ski runs. Most of the runoff from open ski runs is also channeled through sediment detention basins in an effort to reduce the movement of sediment beyond the ski area boundaries.

Compared to other parts of the Sierra Nevada, the potential for significantly increased erosion and sedimentation from off-highway vehicle (OHV) use is relatively small in the eastern Sierra Nevada because of the limited rainfall and snowmelt runoff. However, a critical exception to that statement occurs near and in water courses. When vehicles enter riparian areas and cross streams, there can be significant sediment movement, simply because of the presence of water. There have been anecdotal observations of OHV caused erosion in Glass and Deadman creeks in the past decade. The Inyo National Forest has attempted to address the problem through restricting vehicle use in the Glass/Hartley area. In some areas where vegetation has been damaged and soil has been disaggregated by OHV use, the potential for wind erosion of soil is significantly increased.

Grazing

There was a period of severe overgrazing in the late 1800s to early 1900s throughout the Sierra Nevada that resulted in widespread changes in vegetation cover and composition and active channel erosion. The northern portion of the planning area was assumed to have been impacted in a manner similar to the bulk of the mountain range. An estimated 200,000 head of sheep grazed the Walker River country around 1900 (USDA-Forest Service, 2004). The rangelands have been recovering ever since under less intense grazing pressure.

The upper Owens River watershed may not have been as severely overgrazed in the second half of the 19th century as many other parts of the Sierra Nevada because of the greater distance to markets and population centers. Although we know that Owens Valley ranchers drove livestock into Long Valley and beyond for summer and fall grazing in the 1880s (Burton and Farrell, 1992), there is little other documentation of the extent and intensity of grazing in the upper Owens watershed before 1900. When the first rangers of the Sierra Timber Reserve arrived in Mono County in 1903, their orders were to keep trespassing sheep out of the reserve (Millar, et al., 1996). Overgrazing apparently persisted through the 1940s. In 1944, the Inyo National Forest attempted to bring rangeland use, quantified by animal unit months (AUMs), closer to range productivity and resolve grazing damage to and conflicts with other resources (Millar, et al., 1996). Within six years of adopting that plan, grazing intensity on the whole forest had dropped by 40 percent.

The City of Los Angeles Department of Water and Power leases grazing rights on much of the land in the planning area. Riparian fencing projects for grazing and recreation management on tributaries to the Upper Owens River that were installed in the 1990s demonstrated considerable improvement in riparian conditions (Jellison and Dawson, 2003).

Agriculture and Forestry

In the northern portion of the region, agriculture, primarily cattle ranching, is the dominant land use in the broad Antelope and Bridgeport valleys. Pasture irrigation is the largest single use of agricultural water in Antelope Valley (DWR, 1992). Other areas of large-parcel private land include Little Antelope Valley and the Sonora Junction area. In the early 1970s, there were approximately 38 farms and ranches operating within the West Walker River watershed with a combined area of about 15,870 acres (USDA Nevada River Basin Survey Staff, 1975).

In the 19th century, agriculture was the most extensive land use in the Mono Basin and relied on water diverted from the creeks on the west side of the basin. By the 1890s, perhaps 4,000 acres were irrigated for both crops and pasture (Vorster, 1985). The amount of land under irrigation probably peaked at about 11,000 acres in 1929 (Harding, 1962; cited by Vorster, 1985). As the City of Los Angeles acquired land and water rights in the 1930s, the amount of land under cultivation in the Mono Basin decreased.

Irrigated agriculture in the Owens Valley was practiced for hundreds of years by the native Paiute people who constructed artificial channels to enhance the growth and volume of vegetative resources (Steward, 1934; Lawton, et al., 1976). Euro-Americans began to settle in the Owens Valley in the 1860s and rapidly cleared native vegetation to enable farming (Vorster, 1992). Irrigation canals were constructed, and more than 250 miles of canals and ditches were in place by 1890 (Babb, 1992). This extensive irrigation network allowed most of the average annual flow of the Owens River to be diverted and spread across tens of thousands of acres of cropland and pasture. By 1900, about 15,000 acres were cultivated and another 21,000 acres were intermittently irrigated for pasture (Vorster, 1992). By 1905, the diversion of water from the Owens River for irrigation had led to a 33-foot drop in the level of Owens Lake over the preceding 30 years. By 1913, in response to a few relatively-wet years and reduced irrigation on lands just purchased by the City of Los Angeles, the level of Owens Lake rose about 15 feet (Lee, 1915; Babb, 1992). As the City of Los Angeles acquired most of the land and water rights in the Owens Valley, agriculture declined rapidly. By the early 1990s, about 3,000 acres of alfalfa and other forage crops were irrigated along with about 8,000 acres of pasture, mostly under lease from the City of Los Angeles (Vorster, 1992).

The Walker River watersheds and the Mono Basin were major sources of lumber and fuel wood for the mines near Bodie and Aurora. A five-ton steamer was brought from San Francisco in 1879 to tow barges filled with lumber from Lee Vining Canyon across Mono Lake (Hart, 1996). Apparently, there were so few trees remaining near Lee Vining in the 1920s that lumber had to be brought from Mammoth and Bodie to build the school. In the early 1880s, a railroad was constructed on the east shore of the lake to transport lumber from Mono Mills, on the southeast side, toward Bodie. The logging camp at Mono Mills operated intermittently until 1917 (Hart, 1996).

Timber management on lands of the Inyo National Forest within the upper Owens River watershed has been a relatively small-scale activity compared to other national forests in the Sierra Nevada. Most of the harvesting has occurred in the Dry Creek, Deadman Creek, and Hartley Springs portion of the Glass Creek watershed on the west side of U.S. Highway 395 and the area northeast of Crestview. In the 1960s and 1970s, eight timber sales totaling about 60 million board feet were conducted in the watershed. These harvests removed large Jeffrey pines of high value per tree until about 30 percent to 40 percent of the large trees were cut. By the late 1960s, most of the forest east of the highway had been harvested in this manner, leaving half to two-thirds of the mature trees (Millar, et al., 1996). In 1979, the Inyo National Forest adopted a new plan for the area north of Mammoth Lakes that emphasized timber harvesting with only watershed consequences as a major constraint. Between 1979 and 1988, seven timber sales were harvested with about 30 million board feet of timber cut. As public and agency values shifted during the 1980s and 1990s, an old-growth forest management strategy was developed by the Inyo National Forest (USDA-Forest Service, 1992). During the 1990s wintertime logging was conducted over snow cover in order to protect soils. By 2000, logs were no longer being trucked north out of the area. Currently, most timber harvest is used locally for fuelwood and lumber.

Mining

Following the discovery of gold at Dogtown in the East Walker River watershed, in 1857, prospectors moved south into the Mono Basin and found gold in and near Rattlesnake Gulch in

1858 or 1859 (Fletcher, 1987). The first town in what was to become Mono County, Monoville, grew rapidly around the Mono Diggings. The miners needed water to work the placer deposits and soon built a ditch from Conway Summit to import water from Virginia Creek (DeDecker, 1966).

The headwaters of Lee Vining Creek and Mill Creek were extensively prospected and mined in the 1870s and 1880s. The Great Sierra Silver Mine and Bennettville were established in Mine Creek, a tributary to Lee Vining Creek, between 1878 and 1888. The efforts of hauling mining equipment from Lundy, building the Great Sierra Wagon Road (eventually part of the route of the Tioga Pass road) from the west, boring deep tunnels in hard rock, as well as living at 10,000 feet, made Bennettville and the Tioga Mining District legendary (DeDecker, 1966).

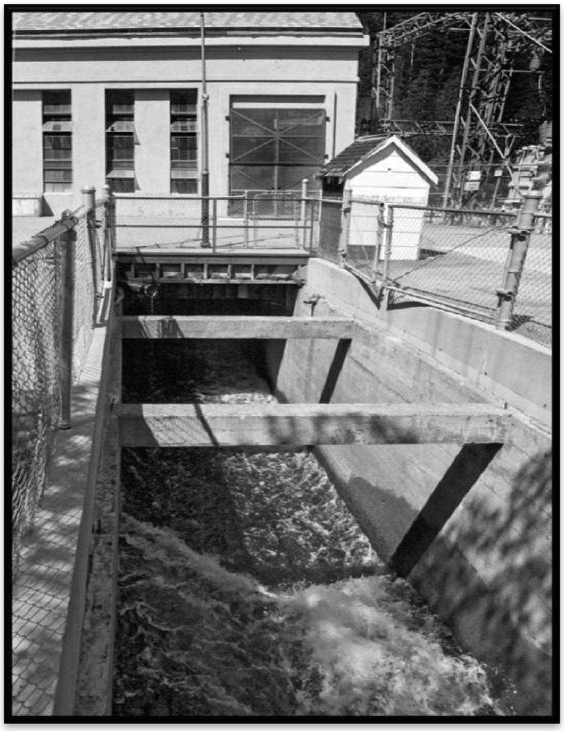
Mining began in the Mammoth Lakes basin in the 1870s and played out relatively quickly. Prospecting throughout the watershed led to active mining in a few locations, but none of the mines was particularly successful. Prospecting and mining occurred all along the eastern slope of the Sierra Nevada, often for short periods following the boom and bust of mineral strikes. For example, Kearsarge City, serving the mines above Independence, was briefly the largest community in Inyo County in the mid-1860s. Mining and processing activities that produced tungsten and molybdenum in Pine Creek were a rare exception to the short mining cycle and persisted for several decades (Kurtak, 1998).

Mining in the northern Mojave region began in the late 1860s and peaked quickly during the 1870s with successful silver mines at Cerro Gordo, Panamint City, Darwin, and Tecopa. Mining of various salts from the lakebeds and playas of the region followed the silver boom. Extraction of borax from Death Valley and Searles Lake was profitable until supply overwhelmed demand by 1888. Gypsum, table salt, talc, potash, and soda ash were profitably mined from China Ranch, Saline Valley, Searles Lake, and other deposits. Mining operations still continue at Searles Lake (Tweed and Davis, 2003) with more than 1.75 million tons of chemicals exported from the Trona processing plant in 2005.

Hydroelectric Generation

In 1893, a hydroelectric generating facility on Green Creek above the Bridgeport Valley began supplying alternating current to the Standard mill in Bodie.

Water from Mill Creek was diverted to generate hydroelectric power in the early years of the 20th century. In 1911, the Lundy Project was completed by the Southern Sierra Power Company (Perrault, 1995). Construction of a dam raised the natural outlet of Lundy Lake 37 feet to an elevation of 7,803 feet (Stine, 1995). Lundy reservoir has a surface area of 130 acres and a usable capacity of about 3,800 AF (Perrault, 1995). The diversion to the Lundy powerhouse has a capacity of about 70 cfs. Southern California Edison assumed ownership and control of the hydroelectric facilities in 1962 as Federal Energy Regulatory Commission project 1390.



Regulation of the flows in Lee Vining Creek for hydroelectric generation began in 1921 (now FERC project 1388). Ellery, Tioga, and Saddlebag reservoirs in the headwaters of Lee Vining Creek have a combined storage capacity of 13,600 acre-feet. Much of the creek's flow is contained within a penstock between Ellery Lake (9,490 feet) and the Poole Powerhouse (7,840 feet). About 27,000 acre-feet of water flows through the powerhouse each year.

Between 1916 and 1925, dams were constructed to enlarge Agnew and Gem lakes and at Rush Creek Meadows to form Waugh Lake to allow storage and regulation of water for the Rush Creek powerhouse near Silver Lake. Waugh, Gem, and Agnew reservoirs can store 4,980; 17,060; and 860 acre-feet, respectively, for Southern California Edison's FERC project 1389.

Following the completion of the Long Valley dam, which regulates Crowley Lake, the LADWP constructed a series of penstocks and power houses downstream in the Owens Gorge. The system began operation in 1953, and the Owens River was effectively dried up within the Gorge. In 1991, an error in the operation of the system damaged a penstock, and water was released back into the natural channel. Once the river began to flow again, the total diversion could not legally resume under the state Fish and Game Code. Managed streamflow, riparian vegetation, and a trout fishery have been restored within the Owens Gorge.

The Bishop Creek hydroelectric system diverts water from the south and middle forks of Bishop Creek and generates electricity at four powerhouses. The system began more than a century ago when the Nevada Power, Mining, and Milling Company began to transmit electricity from their Bishop Creek powerhouse to Tonopah in 1905. Over the following eight years, the Nevada-California Power Company constructed dams that formed South Lake and Lake Sabrina and built five powerhouses that utilized more than 3,500 feet of head. The original wood-stave pipe was replaced between 1949 and 1983 (JRP Historical Consulting Services and California Dept. of Transportation, 2000). The system is now operated by Southern California Edison under FERC license 1394.

LADWP operates hydroelectric facilities on Big Pine Creek, Division Creek, and Cottonwood Creek. The Division Creek powerplant was built in 1905 to supply electricity to help with construction of the aqueduct. In 2008, LADWP proposed the concept of a new hydroelectric plant at Tinemaha Reservoir.

Large-scale solar power projects were proposed on and near Owens Dry Lake in 2010, as well as within the Owens Valley and in more remote parts of southeast Inyo County.

Roads

Many of the roads in eastern Sierra Nevada watersheds have direct impacts on channels and riparian systems because the roads are built on floodplains, in the riparian zone, and/or make frequent crossings of the stream. The most obvious example is U.S. Highway 395 through Walker Canyon. Slopes disturbed by the road placement and construction were long-term sources of sediment to the West Walker River. This section of road was largely destroyed by the flood in January 1997. Portions of other paved roads are often adjacent to or cross major streams. Unpaved forest roads have many areas of contact with streams and riparian zones and are sources of sediment. GIS analyses by Mono County found that the West Walker River watershed contains more than 490 miles of mapped roads that cross streams in at least 380 places, and more than 38 miles of roads are within 100 feet of a stream. In the upper Owens River watershed, the total length of roads is about 1,750 miles, there are more than 1,200 stream crossings by roads, and more than 120 miles of road are within 100 feet of a stream.

Wild and Scenic River Status

The California Wild and Scenic Rivers Act of 1972 preserves designated rivers possessing "extraordinary scenic, recreational, fishery, or wildlife values" in their free-flowing condition. The act prohibits construction of dams, reservoirs, and most water diversion facilities on river segments included in the system (California Department of Water Resources, 1992). The major difference between the national and state acts is that if a river is designated wild and scenic under the state act, the Federal Energy Regulatory Agency can still issue a license to build a dam for hydropower generation on that river. Because of this difference, designation under the National Wild and Scenic Rivers Act (1968) affords enhanced protection (Horton, 1996).

The main channel of the West Walker River from the headwaters near Tower Lake to the confluence with Rock Creek near the town of Walker and Leavitt Creek downstream from Leavitt Falls were added to California's Wild and Scenic River System in 1989. The designated section includes about 33 river miles of the main stem and about 5 miles of the tributary Leavitt Creek (DWR, 1992).

A special provision of the California Wild and Scenic Rivers Act applies to the West Walker River because it is an interstate stream and a source of agricultural water and domestic water:

"The California Wild & Scenic Rivers Act does not prohibit the replacement of diversions or changes in the purpose of use, place of use, or point of diversion under existing water rights, except that no such replacement or change shall operate to increase the adverse effect, if any, of the preexisting diversion facility or place or purpose of use, upon the free-flowing condition and natural character of the stream, and no new diversion shall be constructed unless and until the Resources Secretary determines that the facility is needed to supply domestic water to the residents of any county through which the river or segment flows and that the facility will not adversely affect the free-flowing condition and natural character of the stream."
(http://www.dot.ca.gov/ser/vol1/sec3/special/ch19wsriverschap19.htm#ch19WestWalker)

In 2009, federal Wild and Scenic River status was granted to the headwaters of the Owens River, including Glass Creek and Deadman Creek and portions of the Amargosa River.

Aquatic Conservation Areas

The Sierra Nevada Forest Plan Amendment (aka Sierra Nevada Framework) process of the USDA-Forest Service initiated a series of new aquatic conservation measures. The Humboldt-Toiyabe National Forest applied this management direction to the establishment of several "critical aquatic refuges." These refuges were identified in the Framework amendment as small watersheds that contain:

- known locations of threatened, endangered, or sensitive species
- highly vulnerable populations of native plant or animal species
- localized populations of rare native aquatic- or riparian-dependent plant or animal species

The primary management goal for critical aquatic refuges is to preserve, enhance, restore or connect habitats distributed across the landscape for sensitive or listed species to contribute to their viability and recovery (USDA-Forest Service, 2004).

Land Ownership and Interagency Cooperation

Land ownership in the Inyo-Mono region is primarily public (Figure 2-2). Approximately 94% of Mono County is publicly owned: 88% is owned by the federal government (US Forest Service, National Park Service, Bureau of Land Management, and Department of Defense), 6% by city and state governments, and the remaining 6% is privately owned. The City of Los Angeles owns about 63,000 acres of land in the southern portion of Mono County. Ninety-two percent of Inyo County is federally owned, about 2% is state-owned lands, and the City of Los Angeles owns approximately 4% of the land in Inyo County. The Shoshone and Paiute Indian tribes also own Reservations or Colonies throughout the region.

At the watershed level, a couple of examples from the northern portion of the region illustrate the prevalence of public land. More than 85% of the West Walker River watershed is in public ownership by the U.S. Forest Service, Bureau of Land Management, and the California Department of Fish and Wildlife for resource management purposes (USDA Nevada River Basin Survey Staff, 1975). More than 90 percent of the Mono Basin is USDA-Forest Service, Bureau of Land Management, or Los Angeles Department of Water and Power land. Since 1981, the California Department of Parks and Recreation has also been involved, following the creation of the Mono Lake Tufa State Reserve. The state reserve consists of approximately 6,000 acres of the shoreline of Mono Lake, including landscapes ranging from alkali flats to highly productive wetlands, and the bed and waters of the lake itself. The Inyo National Forest administers the Mono Basin National Forest Scenic Area, established by Congress in 1984. A management plan for the Scenic Area includes some provisions for private property within the boundaries. Mono County and the USDA-Forest Service have different land-use restrictions, both of which must be met by private landowners.

Land use planning within the Inyo-Mono IRWM region is fragmented with respect to the varied ownership of the land. Two federal agencies (U.S. Forest Service and Bureau of Land Management) and the LADWP administer most of the land area. Private land is subject to zoning and planning controls of the county governments or the three incorporated jurisdictions (Ridgecrest, Bishop, and Mammoth Lakes). Within Mono County, the Mono County

Collaborative Planning Team has been somewhat successful in coordinating land use planning among the different agencies since its formation in 1996. Although information exchange has been its primary influence to date, there is great potential through this mechanism to affect general policies and decisions that have widespread consequences.

Part of the public land administered by the Bureau of Land Management, mostly in the vicinity of Crowley Lake, is covered by "watershed withdrawals" made by Congress and the President in the 1930s. The original purpose of these withdrawals was to prevent speculative homesteading in anticipation of acquisition by the City of Los Angeles. The particular status of these lands prevents their sale or exchange, may influence federal water rights appurtenant to these lands, and gives the BLM additional legal status with respect to any hydropower licenses within the designated area.

Demographics, Residential Development, and Economy

Tribal Communities

There are several tribal communities located throughout the Inyo-Mono Region. These communities are the remnants of a widespread Native American population that occupied much of the region prior to Euro-American contact in the mid-1800s. The following is a brief description of tribes and reservations in the region, listed from north to south:

The Washoe/Paiute Tribe of Antelope Valley does not currently have federally recognized status but operates a medical clinic and housing just north of Walker.

The Bridgeport Indian Colony has a federal reservation of 40 acres on the east side of Bridgeport. Although there are more than 100 tribal members enrolled, only about 20 live on the Colony.

Some members of the Mono Lake Paiutes (also known as Kutzadika'a or Kucadikadi) live in and near Lee Vining and are seeking federal recognition. Many members are currently enrolled in federally recognized Paiute, Washoe, Yokuts, Miwok, and Western Mono tribes.

The Utu Utu Gwaitu Paiute Tribe has a 467-acre federal reservation near Benton. The reservation was established in 1915 and currently has about 50 resident members of the tribe.

The Bishop Paiute Tribe has more than 2000 enrolled members and is the fifth largest Native American tribe in California. Since 1912, the Bishop Paiute Tribe has had a federal reservation of 877 acres adjacent to Bishop. About 1500 tribal members live on the reservation.

The Big Pine Band of Owens Valley Paiute Shoshone Indians is a federally recognized tribe. The tribe has more than 450 enrolled members. The Big Pine Reservation covers 279 acres adjacent to the town of Big Pine and was established in 1912.

The Fort Independence Indian Community of Paiute Indians is a federally recognized tribe. Its Fort Independence Reservation has an area of about 350 acres and was established in 1915.

The Paiute-Shoshone Indians of the Lone Pine Community is a federally recognized tribe with about 1400 enrolled members. About 350 tribal members live on the Lone Pine Indian

Reservation that has an area of 237 acres. The reservation was established in 1939 through a land exchange between the U.S. Department of the Interior and the City of Los Angeles.

The Timbisha Shoshone Tribe was formally recognized in 1982, at which time the tribe's reservation, the Death Valley Indian Community near Furnace Creek, was established. During the preceding half-century, the tribe had a difficult relationship with the administration of Death Valley National Monument (now Park). The reservation covered only 40 acres in 1990, but the federal Timbisha Shoshone Homeland Act of 2000 returned 7,500 acres of ancestral lands to the tribe.

A few of the tribes in the region have collaborated on a long-term effort to secure water rights. The Owens Valley Indian Water Commission is a consortium of the Bishop, Big Pine, and Lone Pine Paiute Tribes that is involved with water rights, water and environmental protection, and education.

Other Communities

Compared to most of California, the Inyo-Mono IRWM region is very sparsely populated. Mono County has a population density of about four people per square mile, and Inyo County has only two people per square mile. The City of Ridgecrest within the small part of Kern County that is in the Inyo-Mono IRWM region constitutes about half of the total population of the region (27,616; 2010 Census).

Table 2-6. Population of Inyo and Mono Counties between 1970 and 2010

	1970	1980	1990	2000	2010
Inyo	15,571	17,895	18,281	17,945	18,546
Mono	4,016	8,577	9,956	12,853	14,202

The West Walker River watershed contains four communities: Walker, Coleville, Camp Antelope, and Topaz. The population of Antelope Valley was 574 in 1970 and 1,187 in 1980. The footprint of these communities is quite small. Similarly, in the East Walker River watershed, Bridgeport (county seat of Mono County) is the only community with much population (about 1,000). The economies of these basins are based on agriculture, tourism, government services, and the U.S. Marine Corps Mountain Warfare Training Center and its affiliated housing compound near Coleville.

There are three communities within the Mono Basin: June Lake, Lee Vining, and Mono City. Private property is limited outside these communities. Lee Vining has a population of about 350 people, includes about 20 businesses along U.S. Highway 395, and occupies about 30 acres. Mono City is a community of approximately 100 residents near the junction of U.S. Highway 395 and State Route 167. The year-round population of June Lake is about 650. The communities of Lee Vining and June Lake have economies focused on travelers and tourism. The June Mountain Ski Area attracts winter visitors. These communities serve as centers for hiking, mountain biking, fishing, camping, and skiing.

Mammoth Lakes is the largest community in the upper Owens River watershed, with an area of four square miles and a population of about 8,200. The peak population during holiday periods and busy weekends in 2005 was about 35,000. These large variations in population from day to day have created an unusual set of problems for planning and operations for water supply and sewage disposal as compared to municipalities with relatively stable water demand. The Mammoth Mountain Ski Area is a major driving force in the local economy and the largest employer in Mono County. Other tourism-dependent businesses constitute a significant fraction of economic activity. Residential construction is an episodically important source of employment in southern Mono County.

Ranches along the upper Owens River have remained as relatively large undeveloped parcels, and a few upland areas with access to water along the old Highway 395 have been subdivided in the communities of Aspen Springs, Hilton Creek/Crowley Lake, McGee Creek, Long Valley, and Sunny Slopes. Beyond these communities and Mammoth Lakes, the upper Owens River watershed contains only a few scattered homes.

In the Owens Valley, the principal communities with their respective populations (where available) are Swall Meadows (250), Paradise, Rovana, Starlite, Aspendell, Bishop (4,000), Big Pine (1,400), Independence (600), Lone Pine (700), Keeler (<100), Cartago (110), and Olancha (130). North of Bishop, principal communities are Chalfant and Hammil (700 combined) and Benton and Benton Hot Springs (400 combined). People older than 64 constitute 20 percent or more of the population of the larger communities of the Owens Valley (versus 11 percent of California's population), which suggests that the area is favored by retirees, and a significant proportion of the valley's total income is from transfer payments. The Los Angeles Department of Water and Power is a major employer throughout the Owens Valley.

In the northern Mojave desert zone, the principal communities are Furnace Creek (50), Darwin (50), Trona, Ridgecrest (30,000), Inyokern (1,000), Shoshone (50), and Tecopa (100). Ridgecrest has a vastly greater impact on water resources than the smaller communities. The economy of Ridgecrest is fundamentally tied to the adjacent China Lake Naval Weapons Station.

Descriptive Hydrology

Runoff Generation and Water Balance

The eastern Sierra Nevada part of the Inyo-Mono IRWM planning area has a runoff pattern dominated by snowmelt from April through July that is typical of most Sierra Nevada rivers. A winter snowpack usually begins to accumulate in November at the higher elevations, attains maximum water storage in late March or early April, and then melts over the next 2-3 months. After several months of low discharge during autumn and winter, the streams begin to rise during April with the initial snowmelt and carry sustained high flows through May and into June. As the snowpack gets thinner and snow cover disappears from successively higher elevations, streamflow declines through summer and eventually reaches the minimal flows of autumn. For example, approximately 81 percent of the annual runoff of Mill Creek in the Mono Basin has been attributed to snowmelt, occurring from April through September, and the remaining 19 percent of the annual streamflow occurs as base flow from October through March (Perrault, 1995). Occasionally, a warm winter storm brings enough rainfall over enough of the watershed to raise streamflow for a few days. On rare occasions, these storms lead to significant rainfall and runoff that have generated the largest floods on record.

The northern Mojave Desert zone generates very little runoff, and that runoff is isolated in time and space. Occasional winter storms produce sufficient rainfall to generate runoff from overland flow or downslope water movement through soil layers to a nearby channel. Intense summer thunderstorms can also put a lot of water into channels in a short period of time, creating flash floods. Runoff is also produced by groundwater outflow at seeps and springs. Even where there is some runoff, it often infiltrates back into the bed of the channel not far from the source. Most of the time, most of the channels in the northern Mojave Desert are dry.

A water balance is a useful tool for understanding the various quantities of water involved in different parts of the hydrologic cycle within a particular watershed. Water balances basically show what fraction of incoming precipitation becomes runoff versus what fraction is lost to the atmosphere or adds to groundwater storage.

For example, a coarse water balance (starting with generated runoff from small tributaries) of the entire Walker River basin estimated that 184,700 AF of runoff enter the upper West Walker River and 1,000 AF evaporate before the river enters Antelope Valley. Within Antelope Valley, another 28,700 AF enter and 38,400 AF are lost to evapotranspiration (31,300 AF from irrigated fields, 2,800 AF from phreatophytes, and 4,300 AF from lake surfaces) for a net export from Topaz Lake of 174,000 AF (Carson River Basin Council of Governments, 1974).

A thorough water balance of part of the Owens Valley aquifer system showed how groundwater storage can change over a period of years before and after the second aqueduct to Los Angeles began operation (Table 2-7; Hollett, et al., 1991; Danskin, 1998).

Table 2-7. Water balance for part of the Owens Valley aquifer system for water years 1963-1969 and 1970-1984.

Average Annual Values (AF)		
Component	**WY 63-69**	**WY 70-84**
Precipitation	+2,000	+2,000
Evapotranspiration	-112,000	-72,000
Tributary streams	+106,000	+103,000
Mtn front non-stream recharge	+26,000	+26,000
Runoff from outcrops within fill	+1,000	+1,000
River & Aqueduct seepage	-16,000	-3,000
Spill gates	+6,000	+6,000
Lower Owens River	-5,000	-3,000
Lakes & reservoirs	+1,000	+1,000
Canals, ditches, & ponds	+32,000	+31,000
Irrigation and watering of stock	+18,000	+10,000
Pumped and flowing wells	-20,000	-98,000
Springs and seeps	-26,000	-6,000
Underflow into aquifer system	+4,000	+4,000
Underflow out of aquifer system	-10,000	-10,000
Total recharge	+196,000	+184,000
Total discharge	-189,000	-192,000
Change in groundwater storage	-7,000	+8,000

In this water balance, negative change in storage means water is entering groundwater storage and a positive change in storage means that groundwater is flowing out of storage. The terms are thoroughly explained in the cited reports. The summary is provided here just as an example of a water balance within the Owens Valley.

Streamflow Averages and Extremes

The eastern Sierra Nevada region, especially Owens River watershed, has an unusually high density of streamflow measuring stations, in part because of the high value of the water resources in the area. Streamflow in the eastern Sierra Nevada is highly variable over time, so information about the range in values and the time period considered is at least as important as averages. For example, even on an annual basis, the maximum annual volume for the East Walker River near Bridgeport over the 1926-2011 period of record was more than ten times the minimum annual volume: 321,000 AF in 1983 vs. 27,000 AF in 1931. This range of variability is also illustrated in the extremes in observed annual flow of some of the tributaries to the upper

Owens River (Table 2-8; Smith and Aceituno, 1987).

Table 2-8. Annual flow for five upper Owens River tributaries (cfs)

Stream	Mean	Minimum	Maximum
Convict Creek	26	10	75
Glass Creek	8	2	20
Deadman Creek	6	2	20
Rock Creek	26	13	70
Upper Owens R.	30	15	70

Tributaries to the Owens River from the Sierra Nevada contribute significant volumes of water each year, primarily during the April through July snowmelt-runoff season. Only two streams on the east side of the Owens Valley have any appreciable flow: Coldwater Canyon and Silver Canyon Creek; however, these streams typically discharge less than 2,000 acre-feet/year. In the Inyo Range, Mazourka Creek (USGS station 10282480) was monitored between 1961 and 1972. No flow was recorded all days except during two brief periods in 1967 and 1969. During these periods, discharge peaked at more than 1,300 and 600 cfs, respectively (Hollett et al., 1991; Danskin 1998).

Droughts and Floods

As noted in the climate section, severe and persistent droughts occurred in the West Walker River watershed during AD 890-1110 and 1210-1350 (Stine, 1994). These dry periods had so little streamflow that Jeffrey pine trees grew on the bottom of the channel in the Walker River Canyon. Modern dry spells are short and wet by comparison.

During the past century, periods with well-below average precipitation in the West Walker River watershed occurred in 1924-25, 1928-34, 1960-61, 1976-77, and 1988-92. Topaz reservoir was drained below its operating capacity at times during these dry years. Downstream in Nevada, the Walker River stopped flowing at the Wabuska stream gage in 1924-25 and 1931 (California Department of Water Resources, 1992).

Two serious multi-year droughts occurred in most of the region in the past century: 1923 through 1935 and 1987 through 1992 (Jones and Stokes Associates, 1993a: Appendix H). Streamflow was also much below average in 1976 and 1977. In addition to an occasional dry year, there have been five periods over the past century in which precipitation and resulting runoff in the upper Owens River were well below average for multiple years: 1928 to 1934, 1959 to 1961, 1976 to 1977, 1987 to 1992, and 2000 to 2004. These periods did not correspond exactly with dry periods noted above for the West Walker River.

At the opposite extreme, floods are a basic attribute of channels in the eastern Sierra Nevada and northern Mojave Desert. Hydrologic and geomorphic processes that create alluvial channels tend to make the channel capacity adequate only to handle peak flows that happen with an average frequency of about 1.5 years (or a probability of about 0.67). Peak flows above the channel capacity spill out onto the floodplain and are termed floods. Routine floods rarely have much impact beyond continuing to shape the channel and its adjacent floodplain. However, every few years, various conditions combine to generate considerably larger floods that catch our attention. As the magnitude of floods increases, the frequency of such flows decreases. For example, a very large flood may occur only once in a century (on the average over a very long period of time). This average frequency (sometimes called a return period or recurrence interval) can also be expressed as a probability of occurrence in any given year (*e.g.,* a “one-hundred year flood” has a probability of 0.01 in a particular year).

In the West Walker River, damaging floods occurred in 1950, 1955, and 1997. Prior to the January 2, 1997, peak of about 12,500 cfs, the flood peak of record at the West Walker River near the Coleville gage was 6,500 cfs on December 11, 1937 (California Department of Water Resources, 1992). By contrast, in the adjacent East Walker River, the 1997 flood was only about one-third higher than the previous peak of record (1,910 cfs in 1997 vs. 1,390 cfs in 1963). Floods that cause widespread damage throughout an entire watershed are relatively uncommon. Types of floods in the northern portions of the planning region include winter rain floods, spring snowmelt floods, and localized floods often associated with summer thunderstorms.

Flood damage from the winter rainstorms is most significant in Antelope Valley where low-lying lands can be inundated in even relatively small rainstorms (California Department of Water Resources, 1992). Many lots in the community of Walker, especially between North River Lane and Meadow Drive, are within the 100-year flood plain of the West Walker River.

Snowmelt runoff in 2005 largely filled the channel of the West Walker River within Antelope Valley. In late May, water levels ranged between 8 and 9.2 feet at a gage where 9.0 feet is considered flood stage. Minor flooding was reported between Walker and Topaz. Snowmelt runoff again filled the West Walker River to near flood stage in May, 2006.

In the Mono Basin, floods that were significant from a watershed management perspective occurred in 1967 and 1969 in Rush and Lee Vining creeks. These snowmelt floods of the late 1960s greatly eroded the channels and moved enormous amounts of sediment.

Within the Town of Mammoth Lakes, the 100-year (0.01 probability) peak flow in Mammoth

Creek was estimated at 550 cfs (Environmental Sciences Associates, 1984). Some houses adjacent to the Snowcreek Meadow and immediately downstream could get wet under extraordinary flood conditions, especially if debris jammed the bridges on Minaret and Old Mammoth roads.

Because of the large size of the Owens River watershed (425 mi^2 at Round Valley and 1,975 mi^2 at Big Pine) and its wide range of hydrologic conditions, flood peaks tend to be influenced by the relative timing of peaks in the tributary streams and areal distribution of runoff along with the total volume of water flowing in the main channel (Kattelmann, 1992). Therefore, the largest peak flows at one place along the river do not necessarily coincide with those at other sites along the channel. For example, the largest flood of record (December 12, 1937) on the Owens at Round Valley and Pleasant Valley was attenuated to a comparatively average event by the time it reached Big Pine and Lone Pine. Four floods exceeding twice the mean annual-flood at the gage near Big Pine have occurred during the past century. This index of flood activity is similar to the average for rivers of the western slope of the Sierra Nevada (Kattelmann, 1992). The Los Angeles Aqueduct has been significantly damaged by floods within the Owens Valley on at least four occasions: January, 1943, October, 1945, December, 1966, and August, 1989.

The Amargosa River floods in response to prolonged winter storms as well as intense rainfall during summer. Of the 33 annual peaks recorded at the gage at Tecopa, 20 occurred from July through October and 13 occurred from November through March. The flood of record on the Amargosa at the Tecopa gage was about 10,600 cfs on August 19, 1983. The second highest peak was about 5,000 cfs on February 26, 1969.

Groundwater

Groundwater resources are important throughout the Inyo-Mono IRWM planning area but are particularly valuable in the northern Mojave Desert zone where surface water is severely limited. Most of the aquifers that are pumped in the region are unconsolidated alluvial or lakebed deposits in the vicinity of major streams or Pleistocene lakes. Groundwater infrastructure is most developed in the Owens Valley and Indian Wells Valley. The California Department of Water Resources in its Bulletin 118 (2010) identified about 60 distinct groundwater basins within the Inyo-Mono IRWM planning area (Figure 2-2 and Table 2-4). None of these basins has sufficient data to calculate an adequate groundwater budget. A few of these basins are described below as examples of groundwater resources and use.

Within the West Walker River basin, groundwater is found in two relatively distinct portions of the hydrologic system. Some water is below the ground surface for short periods of time (hours to months) as it flows downslope toward a surface channel or one of the three groundwater basins. This shallow groundwater can be considered as the slow portion of the runoff generation, and most of it ends up as streamflow or is captured by plant roots and lost to the atmosphere. The second type of groundwater can be considered to be in long-term storage (years to centuries), either within fractured bedrock or in the deep groundwater basins of Antelope Valley, Little Antelope Valley, or Slinkard Valley. Alluvial sediments have accumulated to depths of dozens to hundreds of feet within these structural basins and have vast storage space in the pores between the particles. The estimated storage capacities of the groundwater basins of Antelope and Slinkard valleys are 160,000-170,000 and 72,000 AF, respectively (DWR, 1964). These estimates were based on a storage interval between 10 and 100 feet and a specific yield of 5 percent to 15 percent.

A recent report by the California Department of Water Resources contained a little information on groundwater levels within the Antelope Valley. Based on 85 well completion reports, depths ranged from 48-415 feet with an average of about 200 feet. As of now, there is no routine monitoring of well levels reported to the state (DWR, 2004) although that may change with the recent CASGEM reporting requirements. Agricultural irrigation is a significant contributor to groundwater recharge throughout the Antelope Valley. Water infiltrates from the canals, and a lot of applied water infiltrates below the root zone of crops (DWR, 1992).

Because of the lack of data about both the depth of the porous fill material in the Bridgeport Valley and its specific yield, guesses about the storage capacity of the Bridgeport Valley groundwater basin have ranged from 250,000 to 4,000,000 AF.

Groundwater in the Long Valley caldera portion of the upper Owens River watershed can be grouped into three basic categories: a relatively shallow cold-water system (less than 800 feet), a shallow thermal system, and a deep thermal system. The cooler waters are of excellent mineral quality while the warmer (> 80°F) waters have higher concentrations of dissolved solids (USDA-Forest Service, 1994). More than 45 wells have been drilled in the Mammoth Lakes basin since 1976 (USDA-Forest Service, 1994). Out of the first 24 wells, only one yielded good quality water at pumping capacities greater than 200 gallons per minute (well #1, 600 gpm, 500 acre-feet yield). Most of this yield was believed to come from fractured volcanic rocks (Mammoth County Water District, 1981; Gram / Phillips, 1985). Additional wells drilled since 1987 have been more productive (Mammoth Community Water District, 2005).

The main aquifer for the warm springs at the Hot Creek fish hatchery is a fractured basalt flow (Lipshie, 1979). Materials filling the Long Valley caldera include interbedded volcanic rocks (lava flows and tuffs) and sedimentary deposits (lakebeds, stream deposits, and glacial outwash). Fractured lava flows tend to be more permeable than poorly sorted sediments, such as glacial materials (California Department of Water Resources, 1973:31-36). The overall circulation of shallow groundwater is from west to east. An order-of-magnitude estimate of the time required for groundwater to circulate through the system from recharge in the west to discharge at the hot springs along Hot Creek is 100 to 1,000 years (Lipshie, 1979).

The Owens Valley groundwater basin has a surface area of just over 1,000 square miles and a productive aquifer about 1,200 feet thick. Total storage capacity has been estimated to be between 30 and 35 million acre-feet (California Department of Water Resources, 2004). Between 1970 and 1990, groundwater pumping by the Los Angeles Department of Water and Power averaged 104,000 acre-feet per year in the Owens Valley. Since Los Angeles and Inyo County settled litigation over the second aqueduct in 1990, groundwater pumping has averaged 72,000 acre-feet per year. The water table within the city limits of Bishop is largely within ten feet of the surface (Nolte Associates, 2008a).

The Indian Wells Valley groundwater basin (DWR Bulletin-118 #6-54) has a surface area of approximately 600 square miles and is enclosed by the Sierra Nevada on the west, the Coso Range on the north, the Argus Range on the east, and the El Paso Mountains to the south (DWR, 2004). The average depth of basin fill sediments is about 2,000 feet, with more than 7,000 feet of fill in the western portion of the valley (Couch, et al., 2003). A near-surface aquifer that may have been contaminated in parts of the Naval Air Weapons Station at China Lake overlies a regional aquifer at depths of a few tens of feet to several hundred feet below ground surface. Clays deposited in the Pleistocene-age lakes that constitute much of the Indian Wells Valley groundwater basin form a barrier between the shallow and deep aquifers.

The regional aquifer has been extensively utilized to supply water for agriculture, the city of Ridgecrest, town of Inyokern, scattered residences, and the Naval Air Weapons Station at China Lake. The use of water for irrigation in the Indian Wells Valley dates back to an early alfalfa farm in about 1910. Current pumping for irrigation supports alfalfa and various field and orchard crops. In 2001, the largest producers of groundwater in the basin were the Indian Wells Valley Water District (production of approximately 8,400 acre-feet per year), private agricultural users (7,900 acre-feet per year), Naval Air Weapons Station at China Lake (2,800 acre-feet per year), and Searles Valley Minerals (2,700 acre-feet per year) (Couch, et al., 2003).

A large pumping depression is found in the vicinity of the Intermediate Well Field of the Indian Wells Valley Water District. Between 1921 and 1988, groundwater levels declined about 80 feet in this area (Indian Wells Valley Water District, 2002; cited by Couch, et al., 2003). Groundwater levels continue to decline at a rate of 1.0 to 1.5 feet per year near this well field and under Ridgecrest. This groundwater depression results from pumping of the District’s water supply wells, agricultural wells, and private supply wells (Couch, et al., 2003).

Concern has been expressed regarding the sustainability of groundwater as a resource in the Indian Wells Valley. Groundwater production has decreased from about 30,000 acre-ft/yr in the mid-1980s to about 25,000 acre-ft/yr currently. Estimates of overdraft range between 16,000 and 29,000 acre-ft/yr. The primary limitations on quantifying the amount of overdraft are accurately determining recharge into the basin and quantifying well production, particularly from individual agricultural landowners. Groundwater flow directions and gradients are now primarily controlled by pumping from water supply wells (Couch, et al., 2003). A groundwater budget estimated that the volume of annual pumping is about twice the amount of recharge under 1985 conditions (Bean, 1989).

A cooperative groundwater management group is attempting to manage the aquifer system of the Indian Wells Valley. The major users of groundwater in the valley - Indian Wells Valley Water District, Naval Air Weapons Station at China Lake, and Searles Valley Minerals - have prepared a plan with the goal of extending “the useful life of the groundwater resources to meet current and foreseeable user needs in the Valley” (Indian Wells Valley Cooperative Groundwater Management Group, 2006).

Water Demand and Projections

The principal uses for water in the Inyo-Mono IRWM planning area are agriculture and export. A best guess for water applied to irrigated fields and pastures is 250,000 to 350,000 acre-feet per year, based on about 90,000 acres of irrigated land in the two counties and an average application of 3 to 4 feet of water per season. The applied amount varies from 2.4 feet in the Bridgeport Valley (Lopes and Allander, 2009) to about 5 feet on lower-elevation fields leased from LADWP. The quantity of surface and groundwater exported to Los Angeles is better known with an average of 356,000 acre-feet per year between 1970 and 2011 (LADWP, 2011a). Over the past ten years, the average export amount has dropped to about 228,000 AF (based on data from LADWP, 2011a). Environmental water demands in the region are primarily related to LADWP mitigation programs. In 2011, these uses amounted to about 95,000 AF for Owens Lake dust abatement, 16,500 AF for the Lower Owens River Project, 10,500 AF for enhancement and mitigation projects, and 10,400 AF for recreation and wildlife (LADWP, 2011a). Residential/commercial demands involve much smaller quantities of water because of the low population in the region. Industrial and military demand is very small outside of the Ridgecrest and China Lake area.

In rural parts of Mono County, households with extensive lawn and garden irrigation have used between 200 and 400 gallons per day per capita (Gram/Phillips Associates, 1980). Where outside watering is modest, per capita water use in Mono County is 125 to 150 gallons per day. A national survey of water use (Kenny, et al., 2009) suggested that average per capita use in Mono County is about 270 gallons per day. A different interpretation of presumably the same data produced a figure of 472 gallons per day (Sacramento Bee, 11/26/2008 – web page not currently active). Because very little land is available for development, significant population growth is not anticipated in Mono County, and domestic consumption totals should grow at relatively slow rates (less than 0.1 percent per year). Nevertheless, there could be local inadequacies in water supply because whatever growth occurs will be concentrated in relatively small areas.

Within the town of Mammoth Lakes, water demand grew rapidly until the past few years when it has declined in response to delivery of recycled water to a golf course, water conservation, and reduction of leaks. Total water use within the town was 2,565 acre-feet in 1992; 2,641 acre-feet in 1995; 3,287 acre-feet in 2001; 3,421 acre-feet in 2005; and 2,961 acre-feet in 2010 (Mammoth Community Water District, 2005 and 2011a). Based on the town's population of 8,200 in the 2010 census, annual water use of 2,169 acre-feet per year is equivalent to about 243 gal per day per capita. However, the town hosts a large transient population of recreational visitors, owners of second homes, and seasonal workers that account for a significant fraction of the water use (Kattelmann and Dawson, 1994; Mammoth Community Water District 2011a). In summer, much of the landscaping around housing units is irrigated regardless of occupancy and accounts for significant water demand. The town's current Urban Water Management Plan (Mammoth Community Water District, 2011a) projects demand for 2020 at about 3,400 acre-feet per year and for 2030 at about 4,200 acre-feet per year.

In Bishop, average daily demand per capita between 1997 and 2006 ranged from 400 to 490 gallons per day (Nolte Associates, 2008a). A national survey of water use (Kenny, et al., 2009) suggested that average per capita use in Inyo County is about 470 gallons per day. A different interpretation of presumably the same data produced a figure of 439 gallons per day

(Sacramento Bee, 11/26/2008 – web page not currently active). About 1.6 million gallons of water per day were supplied by the City of Bishop Department of Public Works in 2004. The maximum daily demand was 4 million gallons per day. About half the city's water use occurs from June through September. There is very little undeveloped private land within the boundaries of Bishop and therefore, little opportunity for growth and related increases in water demand. However, if vacant properties currently owned by LADWP within the Bishop city limits were to be made available and developed, then the average water demand at full build-out could rise to 5.7 million gallons per day (70 percent commercial and 30 percent residential) (Nolte Associates, 2008a).

Water demand within the Indian Wells Valley Water District has averaged about 8,800 acre-feet per year or about 280 gallons per day per capita. Potential increases in demand have been forecast in the Indian Wells Valley groundwater basin (Couch, et al., 2003). Although demand within the Indian Wells Valley Water District is anticipated to increase about 2 percent per year through 2020 and individual well use is forecast to increase about 1 percent per year, decreased demand by the Naval Air Weapons Station at China Lake and the Inyokern Community Services District results in a net increase in demand of only about 0.1 percent per year (Couch, et al., 2003).

Environmental water demand can be considered as either natural or regulatory. Evapotranspiration from lakes, soils, and native (or at least unmanaged) vegetation uses a large fraction of the precipitation that falls in the planning area – about half in high-elevation catchments and approaching 100 percent in low-elevation desert areas. In recent years, the term "environmental water demand" has also come to be used for managed water that is required to be used for some environmental benefit, such as a minimum instream flow to maintain fish and other aquatic species or sufficient water to support wetlands and riparian areas. As part of their water rights licenses, LADWP must now leave defined amounts of water in Mono Lake tributaries, and the Mammoth Community Water District does not divert water from Mammoth Creek when prescribed minimum flows are not met.

Water supplies for the Inyo-Mono IRWM region are forecast to remain largely as they are today: variable and uncertain. Water is not imported into the region, and there are no plans to do so. Political and legal action in the Walker River basin could eventually result in transfers of water out of irrigation to provide more water for Walker Lake. Proposed geothermal energy expansion near the community of Mammoth Lakes has the potential to alter groundwater flow and thereby impact water supplies for the town. Climate change has the potential to increase variability of precipitation, change the average amount of precipitation, increase the proportion of rainfall (versus snowfall), and alter the timing of snowmelt runoff. In the Indian Wells Valley, declining groundwater levels may increase pumping costs and thereby increase the cost of water supply.

Diversions, Storage, and Use

Water storage and transfers in the Inyo-Mono IRWM planning area are dominated by the Los Angeles Aqueduct system Major components of the LADWP water export and power generation system include a series of reservoirs and a tunnel for exporting water from the Mono Basin to the Owens River headwaters; the Crowley Lake reservoir in Long Valley; diversions in the Owens River Gorge for power generation; hydropower generation on Big Pine, Division, and Cottonwood Creeks; the Tinemaha, Pleasant Valley, and Haiwee Reservoirs; extensive groundwater pumping capacity, and the Los Angeles Aqueduct. Los Angeles' land and water ownership and extensive infrastructure along the east slope of the Sierra Nevada link many water management issues in the western part of the Inyo-Mono IRWM region and to other IRWM planning regions in southern California.

Within the Mono Basin, LADWP diverted as much as 134,600 acre-feet and as little as 15 acre-feet between 1941 and 1980. After the completion of the second aqueduct, LADWP diverted more than 100,000 acre-feet annually, except during 1976-77 drought (Hashimoto and Qasi, 1981). Diversions were halted by court order from 1989 to 1994. Starting in 1995, diversions up to 16,000 acre-feet per year resumed under SWRCB Decision 1631.

In the upper Owens River watershed, Crowley Lake was created by construction of Long Valley dam in the early 1940s. The reservoir is the main storage within the LA Aqueduct system and has a capacity of 183,000 acre-feet. At the other end of the Owens Gorge, Pleasant Valley Reservoir was built in 1955 to modulate flows released from the hydroelectric facilities in the Owens Gorge. This reservoir can store up to 3,825 acre-feet. Closer to the aqueduct intake, Tinemaha Reservoir stores up to 16,000 acre-feet.

LADWP also operates an extensive dust abatement project on the Owens Lake playa that relies heavily on shallow flooding to control dust. The dust abatement project currently budgets about 95,000 AFY and has used up to 75,800 AFY. LADWP also provides water for other uses within the Owens Valley that include irrigation, stockwater, enhancement and mitigation projects, the Lower Owens River Project, and recreation and wildlife projects. Water volume for all uses within the Owens Valley added up to about 202,000 AF in the 2011-12 runoff year (LADWP, 2011a).

The largest diversions from the West Walker River occur at the Nevada end of the state-boundary-defined watershed. In the northern portion of the Antelope Valley, water from the West Walker River is diverted into Topaz Reservoir, where it is stored for controlled release to irrigators downstream in Nevada. The Walker River Irrigation District created Topaz Lake by constructing a diversion and three-mile-long canal from the West Walker River into a small closed basin in 1921. A tunnel and canal release water back into the river on the Nevada side (DWR, 1992).

Within Antelope Valley, the West Walker River has been diverted into canals for local irrigation for more than a century. About 11 miles of the river are affected by these diversions, which can reduce the late-summer discharge to a series of marginally connected pools (Lahontan Regional Water Quality Control Board, 1975).

Upper and Lower Twin Lakes reservoirs on Robinson Creek were constructed around 1900 to regulate irrigation supplies for the Bridgeport Valley. The two reservoirs have a combined storage of 6,100 acre-feet and have water rights for refilling during the irrigation season. Bridgeport Reservoir was constructed in 1924 by the Walker River Irrigation District to store water for summer irrigation downstream in Smith and Mason Valleys. The reservoir has a storage capacity of about 44,000 acre-feet (California Department of Water Resources, 1992).

In the Mono basin, water from Mill Creek was diverted to generate hydroelectric power in the early years of the 20th century. The diversion to the Lundy powerhouse has a capacity of about 70 cfs. Regulation of the flows in Lee Vining Creek for hydroelectric generation began in 1921 (now FERC project 1388). Ellery, Tioga, and Saddlebag reservoirs in the headwaters of Lee Vining Creek have a combined storage capacity of 13,600 acre-feet. About 27,000 acre-feet of water pass through the powerhouse each year. Between 1916 and 1925, dams were constructed to enlarge Agnew and Gem lakes and at Rush Creek Meadows to form Waugh Lake to allow storage and regulation of water for the Rush Creek powerhouse near Silver Lake. Waugh, Gem, and Agnew reservoirs can store 4,980, 17,060, and 860 acre-feet, respectively, for Southern California Edison's FERC project 1389. There is a small dam on Walker Lake operated by LADWP that formerly was used to fill additional storage in May and was emptied in November. Due to extremely low flows that killed fish in Walker Creek below the dam during the May 2003 filling, the reservoir is now kept full year-round.

In the Mammoth Lakes basin, Lake Mary, Lake Mamie, and Twin Lakes are controlled by outlet structures, and their water levels change seasonally. The Mammoth Community Water District has appropriative water rights to 5 cfs or 2,760 acre-feet/year to divert water from Mammoth Creek (Lake Mary) subject to State licenses and permit conditions and a Master Operating Agreement with the U.S. Forest Service.

During a period of great interest in small hydroelectric projects in the eastern Sierra Nevada in the late 1970s and 1980s, the Department of Fish and Game compiled statistics about the proportion of average discharge diverted in each stream and the stream length affected by the upstream diversion on each stream (Shumway, 1985). The following table illustrates the effects of diversion of some example streams within the upper Owens River watershed:

Table 2-9. Diversion effects on streams in the upper Owens River watershed

Stream	Average discharge (acre feet)	% Diverted	Length affected/total (miles)
Convict	18,600	29	7.0/7.1
Crooked	9,100	63	1.1/1.4
Hilton	8,130	17	1.4/4.4
Laurel	6,180	27	4.0/4.7
Mammoth	21,900	38	8.4/11.6
McGee	22,400	29	5.4/6.6
O'Harrel Cyn	72	3	0.5/3.0
Sherwin	4,700	<1	1.0/1.7

The Bishop Creek hydroelectric system diverts water from the south and middle forks of Bishop Creek and generates electricity at four powerhouses. The system began more than a century ago when the Nevada Power, Mining, and Milling Company began to transmit electricity from their Bishop Creek powerhouse to Tonopah in 1905. During the following eight years, the Nevada-California Power Company constructed dams that formed South Lake and Lake Sabrina and built five powerhouses that utilized more than 3,500 feet of head. The system is now operated by Southern California Edison under FERC license 1394. Lake Sabrina and South Lake have storage capacities of about 7,500 and 12,500 acre-feet, respectively.

Water Suppliers

The following paragraphs describe a sample of the water suppliers in the region. Areas not otherwise mentioned have individual wells or other household supply or are served by mutual water companies with a small service population. The populations served by water systems within the planning area are summarized in Table 3-10.

Bridgeport Public Utilities District

The Bridgeport Public Utility District supplies water to the town (population 600) from two wells. In 1990, the total demand was about 243 acre-feet (DWR,1992). BPUD connections are not metered. BPUD also provides water to the Bridgeport Indian Colony reservation.

Lundy Mutual Water Company

The Mono City water system had 71 hookups as of August, 2005, served by a community well and storage tank. The water use is not currently metered, and there is no chlorination on a regular basis. Annual water use is about 27 acre-feet with about half of that lost to the atmosphere (USDA-Forest Service, 2003). A member of the Mono City water board mentioned at the August, 2000, Mono County planning commission meeting that the water system was "about maxed out."

Lee Vining Public Utility District

After World War II, the population of Lee Vining reached about 200, and the Lee Vining Public Utility District was formed. The district extended an existing supply pipe upstream above where there was any possibility of contamination from the Log Cabin Mine and built Mono County's first sewer system. The next upgrade was relocation of the intake to the forebay of the lower SCE powerhouse on Lee Vining Creek. In the 1950s, a 180,000-gallon storage tank was constructed on land provided by SCE, and investigations began of a spring as an alternative to the creek water. After the spring was developed and connected to the Lee Vining supply system, the town's residents no longer suffered a seasonal ailment, locally known as the "Lee Vining pip," that was thought to result from lodgepole pine pollen in the water supply from the creek. The spring continues to serve Lee Vining and has been a reliable water source for a half century. A second storage tank was added about a decade ago in order to meet summertime peak hourly demand. The Lee Vining water system is routinely inspected and tested by technicians from the June Lake PUD. Lee Vining PUD began adding chlorine to its system a few years ago to meet state requirements.

June Lake Public Utility District

The June Lake Public Utility District serves the June Lake Loop area. The boundaries include an area of approximately 1,720 acres of unincorporated residential, commercial and undeveloped land. The district provides water to three distinct areas: the Village, West Village and Down Canyon, as well as the outlying areas of Pine Cliff, Oh! Ridge, and June Lake Junction. Water is obtained from Snow Creek, June Lake, Fern Creek, and Yost Creek (Boyle Engineering Corporation, 2004).

Initial construction of the Village water system, including the Snow Creek diversion facility, occurred in the 1940s. In 1972, an intake from June Lake was added, along with a filtration plant and storage tank. All of the water was drawn from June Lake between 1975 and 1978. After the Snow Creek diversion and filtration plant were completed in 1978, Snow Creek became the primary water source, and June Lake water was only used in summer months (Triad/Holmes Associates, 2004).

Water demand in the entire service area corresponds to the number of visitors to the area. The water needs of the permanent population (about 700) constitute a relatively small portion of the total water demand. The visitor population can exceed 3,000 persons on weekends and holidays (Boyle Engineering Corporation, 2004). The annual demand in 2004 was about 143 acre-feet in the Village system and about 225 acre-feet in the Down Canyon system (ECO:LOGIC Consulting Engineers, 2006).

If the proposed Rodeo Grounds development is built, that area could be densely populated with accommodations for as many as 7,000 visitors and permanent residents. Estimation of potential water demands for the development at buildout assumed the average day demand for visitors would be 75 gallons per capita per day (gpcd) and 100 gpcd for permanent residents. A more recent study estimated the total annual demand for the proposed project as about 33 million gallons or about 102 acre-feet (ECO:LOGIC Consulting Engineers, 2006).

Mammoth Community Water District

Beginning in 1958, the Mammoth County (now Community) Water District has supplied water and wastewater services to Mammoth Lakes. Until the mid-1970s, water diverted from Mammoth Creek was adequate to meet needs of up to 1,400 acre-feet/year. In 1978, the district obtained a permit from the State Water Resources Control Board to divert additional water. The permit includes several conditions that attempt to limit the impacts of the water diversion on the Mammoth Creek fishery. The District has also pursued groundwater well development, promotion of water conservation, system leakage repairs, and production of reclaimed water for irrigation. Although the resident population is currently about 8,200, instantaneous population on weekends and holidays often increases by up to four times for short periods. This high variability in demand is unusual among water supply utilities. The Mammoth Community Water District has applied the Town's estimates of peak population numbers and transient occupancy rates to determine an "effective annual population" to account for the variability in daily demand in its current Urban Water Management Plan (Mammoth Community Water District, 2011a).

Total water use (delivered plus unaccounted water) within the district was 2,565 acre-feet in 1992; 2,641 acre-feet in 1995; 3,287 acre-feet in 2001; 3,421 acre-feet in 2005; and 2,691 acre-feet in 2010 (Mammoth Community Water District, 2005 and 2011a). The District's most recent assessment determined that there is sufficient water from existing supplies and one new planned groundwater production well to meet demands under a range of water year types. The existing supplies and current use were quantified as a maximum of 2,760 acre-feet from surface water and 3,400 acre-feet from groundwater. A study for the district estimated that a total volume of 3,800 acre-feet could be pumped from groundwater within the Mammoth Basin (generally within town boundaries) without significant impacts to streams or springs within the basin (Wildermuth Environmental, Inc., 2003).

Communities of Southern Mono County

The communities of Hilton Creek/Crowley Lake, Sunny Slopes, Pinyon Ranch, Paradise, and portions of Swall Meadows rely on groundwater supplied by community service districts or mutual water companies. In the Hilton Creek/Crowley Lake community, water use in 1980 was estimated at approximately 150 gallons per capita per day. Based on the average population figures for Crowley Lake, the estimated total domestic water use in the service area was about 50 AF per year in 1980 and was projected to be 110 AF per year in 1998 (Gram/Phillips Associates, 1980). Another estimate of typical water-use in the area is 440 gallons per day (gpd) for a single-family residence (Triad Engineering, 1994). The equivalent per capita rate is 125 gpd, assuming an average household of 3.5 people. During the summer irrigation season, daily demands typically approach 1,350 gpd per household or three times the annual average (Triad Engineering, 1994).

Three studies of groundwater resource availability in the Hilton Creek/Crowley Lake community were reported for the Mountain Meadows Mutual Water Company (Triad Engineering, 1994):

Table 2-10. Groundwater availability in Hilton Creek/Crowley Lake

Groundwater Resource Availability in the Hilton Creek/Crowley Lake Community	
Slade and Blevins, 1979	25-30 acre-feet/year
Gram/Phillips, 1980	330 acre-feet/year
Kleinfelder, 1983	407 acre-feet/year

The eventual water system demand has been estimated at 160 acre-feet/year (Triad Engineering, 1994).

In the past few years, one of the principal wells for the Hilton Creek/Crowley Lake community has been found to contain excessive levels of naturally-occurring radionucleides.

City of Bishop

The City of Bishop Department of Public Works supplies water to all residents and businesses within the city limits that enclose about 1.8 mi^2. The basic infrastructure consists of three wells, a million-gallon storage tank, disinfection facility, and pipelines. The average daily demand per capita over the period 1997 through 2006 varied between 390 and 490 gallons per day (Nolte Associates, 2008a).

Because much of "greater Bishop" is outside of the official limits of the City of Bishop, other water agencies supply more water to more people than does the City of Bishop Department of Public Works. The larger water purveyors include the Bishop Paiute Tribe, Highland Mobile Home Park, Indian Creek / Westridge Community Services District, Meadowcreek Mutual Water Company, and Sierra Highlands Community Services District. A large section of west Bishop is served by individual wells for interior domestic use and an extensive ditch network for irrigation of landscaping. The ditch system is critical to recharging the local groundwater and requires careful management. For example, the drought of 2013-2014 resulted in dry ditches and a rapidly declining water table through March 2014. Then, the initial flush of water in the ditches during April and May replenished groundwater in a surprisingly fast manner and even led to flooding of some basements in west Bishop. The Bishop Creek Water Association attempts to coordinate activities involving the ditch system between Southern California Edison, LA Department of Water and Power, Bishop Paiute Tribe, and homeowners.

Communities of Southern Owens Valley

Water is supplied to Big Pine by the Big Pine Community Services District and Rolling Green Utilities, Inc. Inyo County currently supplies water to the communities of Laws, Independence, and Lone Pine, but a community services district structure is planned for these communities. The Cartago Mutual Water Company is the water supplier for Cartago.

The largest industrial water user in the Owens Valley is also a water exporter because its product is bottled water. The Crystal Geyser Roxane facility at Cartago on the west side of Owens dry lake pumps groundwater for bottling and has a design capacity of about 150 acre-feet per year (Quad Knopf, Inc., 2004).

Indian Wells Valley

In the largest population center of the Inyo-Mono IRWM region, the Indian Wells Valley Water District is the primary water supplier for the city of Ridgecrest. The District's domestic water system consists of 12 well pumping plants, 9 booster pumping plants, 10 water storage reservoirs, and more than one million linear feet of transmission and distribution pipelines (Krieger & Stewart 1998). Recently, IWVWD constructed two arsenic treatment facilities to help alleviate the water quality issues of their pumped groundwater. Growth in the District's service area is forecast to increase from approximately 27,000 in 2000 to approximately 34,100 by 2020 (Indian Wells Valley Water District, 2002). Total groundwater pumping in the Indian Wells Valley by the District and other users is forecast to rise from 21,400 acre-feet per year in 2002 to about 22,900 acre-feet per year in 2020 (Couch, et al., 2003).

The Inyokern Community Services District serves approximately 420 households according to U.S. Census Bureau data for 2000. In 2001, the Inyokern Community Services District used 97 acre-feet/year of water. Water use has been steadily declining since the mid-1980s. This can be primarily attributed to reductions in the work force at NAWS China Lake.

Table 2-11: Mono, Inyo, Kern, and San Bernardino County principal water systems in the Inyo-Mono IRWM planning region (sources: EPA State Drinking Water Information Systems: *http://iaspub.epa.gov/enviro/sdw_form_v2.create_page?state_abbr=CA* and Environmental Working Group: http://www.ewg.org/tap-water/home and personal communication)

Mono County Public Water System Name	Population Served
AJ S MARKET	25
ARCULARIUS RANCH	35
BENTON COMMUNITY CENTER	25
BENTON SENIOR CITIZENS CTR	25
BENTON STATION	25
BIG BEND CAMPGROUND	70
BIG MEADOW CAMPGROUND	50
BIRCHIM COMMUNITY SERVICE DIST	130
BOOTLEG CAMPGROUND	315
BRIDGEPORT PUD	850
BRIDGEPORT RESERVOIR BOAT LNG	25
BROWN S OWENS RIVER CAMPGROUND	60
BUCKEYE CAMPGROUND	370
CAL TRANS - CRESTVIEW REST AREA	300
CAMP ANTELOPE	40
CHALFANT COMMUNITY CENTER	25
CHRIS FLAT CAMPGROUND	75
COLEVILLE HIGH SCHOOL	90
CONVICT LAKE CAMPGROUND	400

Mono County Public Water System Name	Population Served
CROWLEY LAKE CAMPLAND	25
CROWLEY LAKE FISH CAMP	25
CROWLEY LAKE GENERAL STORE	25
CROWLEY LAKE MUT. WATER DIST.	250
CROWLEY LAKE PARK	25
CROWLEY LAKE TRAILER PARK	130
CROWLEY LAKE TRAILER PARK	130
CRYSTAL CRAG WATER & DEVELOP.	75
CSP - BODIE SHP	2,506
DOC & AL S	100
EAST FORK CAMPGROUND	200
EDNA BEAMAN ELEMENTARY SCHOOL	90
ELLERY LAKE CAMPGROUND	50
FRENCH CAMPGROUND	150
GRANT LAKE MARINA REST/STORE	130
GREEN CREEK CAMPGROUND	75
HISTORIC MONO INN	25
HOT CREEK HATCHERY	25
HOT CREEK RANCH	25
HUNEWILL GUEST RANCH	50
JUNE LAKE P.U.D.-DOWN CANYON	360
JUNE LAKE PUD VILLAGE	360
JUNE MTN. SKI AREA, STEW POT SLIM S	50
JUNE MTN. SKI AREA, STEW POT SLIM S	500
LEAVITT CAMPGROUND	110
LEE VINING PUD	350
LEE VINING RANGER STATION	25
LOG CABIN WILDERNESS CAMP	100
LOWER ROCK CREEK MUTUAL WATER CO.	200
LOWER SWALL MEADOWS WATER SYSTEM	40
LUNDY LAKE RESORT	70
LUNDY MUTUAL WATER COMPANY	70
MAMMOTH CWD	8,237
MAMMOTH LAKES AIRPORT	25
MAMMOTH LAKES BASIN	1,000
MAMMOTH MTN SKI AREA- OUTPOST 14	1,000
MCGEE CREEK CAMPGROUND	120
MCGEE CREEK MOBILE HOME PARK	20
MEADOWCLIFF RESORT	25
MONO LAKE COUNTY PARK	25

Mono County Public Water System Name	Population Served
MONO VILLAGE REST./STORE	500
MOUNTAIN MEADOWS MWC	225
MOUNTAIN VIEW BARBECUE	25
OLD BRIDGEPORT RANGER STA. COMPOUND	25
PARADISE SHORES RV PARK	20
PINE GROVE CAMPGROUND	30
PINEGLADE ASSOCIATION	50
POKONOBE LODGE RES./STORE	100
POKONOBE LODGE REST./STORE	100
ROBINSON CREEK CAMPGROUND	680
ROCK CREEK LODGE	23
SADDLEBAG LAKE CAMPGROUND	100
SIERRA EAST HOME. ASSOC.	50
SONORA BRIDGE CAMPGROUND	50
TIOGA GAS MART	50
TIOGA LAKE CAMPGROUND	50
TIOGA PASS RESORT	100
TOM S PLACE	25
TOPAZ LAKE MOBILE HOME PARK	25
TOPAZ LAKE RV PARK	170
TRUMBULL LAKE CAMPGROUND	100
TUFF CAMPGROUND	80
TWIN LAKES ENT.	300
TWIN LAKES RESORT	100
TWIN LAKES STORE	50
USMC HOUSING - COLEVILLE	361
USMC/MTN WARFARE TRNG CTR - BRIDGEPORT	300
VIRGINIA CR. SETTLEMENT PARK	40
VIRGINIA LAKES MUTUAL WATER CO.	150
WALKER BURGER	25
WALKER COMMUNITY HALL AND PARK	25
WALKER RIVER RV & ESPRESSO BAR	25
WHITE MOUNTAIN ESTATES	50
WHITMORE BALLFIELDS	30
WHITMORE POOL	50
WILLOW SPRINGS MOTEL AND RV PK	60
WOODS LODGE	75
YMCA CAMP OF LOS ANGELES #1	150

Inyo County Public Water System Name	Population Served
Aberdeen Water System	150
Aspendell Mutual Water Company	60
Baker Creek Campground	100
Bernasconi Education Center	50
Big Pine Creek Campground	100
BIG PINE CSD	1,000
Big Trees Campground	50
Bird Industrial Complex	45
Bishop, City of	3,879
Bishop Country Club	400
Bishop Creek Lodge	58
Bishop Creek System	80
Bitterbrush Campground	100
Boulder Creek Trailer Park	50
Brookside Estates Mutual Water Company	45
Brookside Mobile Home Park	136
CAL TRANS - COSO JUNCTION	500
CAL TRANS - DIVISION CR.	300
Cardinal Village Resort	55
Cartago Mutual Water Company	132
CDF - OWENS VALLEY CONSERVATION CORP	250
Charles Brown Water Company	330
Comfort Inn	150
Control Gorge Power Plant	36
Coso Junction Ranch Store	1,000
CR Briggs Corporation	50
Crystal Geyser Bottling Plant	100
Darwin Community Service District	60
Death Valley Junction	200
DEATH VALLEY, SCOTTY S CASTLE	50
Deep Springs College	40
Delight s Hot Springs Resort	55
Diaz Lake Campground	4,000
Eastern Sierra College Center - Bishop	100
Eastern Sierra Regional Airport	50
Eastern Sierra Tri County Fair	100
Foothill Lone Pine Mobile Home Park	100

Inyo County Public Water System Name	Population Served
Four Jeffrey Campground	318
Glacier Lodge	50
Glenwood Mobile Estates	300
Gray s Meadow Campground	50
Gus Water	100
High Sierra Water Company	200
HIGHLAND MOBILE HOME PARK	900
Horseshoe Meadow Campground	70
Horton Creek Campground	50
INDIAN CREEK COMMUNITY SERVICE DISTRICT	1,000
INYO COUNTY PWD - INDEPENDENCE	574
INYO COUNTY PWD - LONE PINE	1,655
Katherina Muller Water System	250
Keeler Community Service District	180
Keeler Yard LADWP	70
Keough s Hot Springs	40
LADWP - INDEPENDENCE	586
LADWP - LONE PINE	1,118
Lake Sabrina Boat Landing	35
Laws Town Inyo County	30
Laws Town LADWP	30
Lone Pine Campground	45
MANZANAR NATIONAL HISTORIC SITE	298
Meadow Lake Apartments	35
MEADOWCREEK MUTUAL WATER COMPANY	640
Millpond Recreation Area	500
Mount Whitney Fish Hatchery	50
Mount Whitney Golf Club	100
Mountain View Trailer Court	25
North Lake Campground	30
North Lone Pine Mutual Water Company	70
NPS - DEATH VALLEY, FURNACE CR.	150
NPS - DEATH VALLEY, GRAPEVINE RS	25
NPS - DEATH VALLEY, MESQUITE SPRGS.	25
NPS - DEATH VALLEY, STOVEPIPE WELLS	30
NPS - DEATH VALLEY, WILDROSE CMPGD	35
NPS - DVNM - COW CR/NEVARES	125
NPS-DEATH VALLEY EMIGRANT REST AREA/CG	25
Olancha RV and MHP	30
Onion Valley Campground	25

Inyo County Public Water System Name	Population Served
Owens Valley Water Company	300
Palisade Glacier High School	50
Panamint Springs Resort	200
Parcher s Resort	45
Park West Mutual Water Company	200
Pearsonville Water System	100
Petite Pantry	100
Pine Creek Village	350
Pleasant Valley Campground	100
Primrose Lane Apartments	36
Ranch House Cafe	150
Ranch Road Estates Mutual Water Company	65
Rawson Creek Mutual Water Company	100
Rock Creek Lake Boat Dock & Group Camp	50
Rock Creek Lake Campground	210
Rock Creek Lakes Resort	56
Rocking K Ranch Estates Mutual Water Co.	30
ROLLING GREEN UTILITIES, INC.	800
Round Valley School	140
Sabrina Campground	30
Sage Flat Campground	28
SCE Bishop Creek Plant 4	45
Schober Lane Campground	150
Sierra Grande Estates Mutual Water Co.	200
SIERRA HIGHLAND CSD	500
Sierra North Community Service District	28
Starlite Community Service District	175
Sunland Village Mobile Home Park	42
Taboose Creek Campground	50
Tecopa Francis Elementary School	30
Tecopa Hot Springs Park	100
Tecopa Palms RV Park	50
Tuttle Creek Campground	50
Upper Sage Flat Campground	28
Valley Vista Mutual Water Company	75
Van Loon Water Association	30
White Mountain Research Station	45
Whitney Portal	500
Wilson Circle Mutual Water Company	100

Kern & San Bernardino County Water Systems	Population Served
Indian Wells Valley Water District	34,900
Naval Air Weapons Station China Lake	6,000
Inyokern CSD	984
East Inyokern Mutual Water	87
Searles Valley Minerals Operations, Inc.	2,300

The above tables only include currently active public water systems. A complete list of water systems, both active and inactive, in the three counties is available from the California Department of Public Health's Drinking Water Information Clearinghouse website: (http://drinc.ca.gov/DWW/Maps/Map_Template.jsp).

Urban Runoff and Stormwater Management

Concerns about pollution from stormwater runoff from urban areas began to be raised in the 1950s and 1960s. The principal pollutants that can be expected in urban runoff include sediment, oils and grease, rubber compounds, nutrients, pesticides, bacteria and viruses, and metals. The materials that are likely to be found on streets, gutters, and parking lots typically get removed in the first flush of stormwater runoff. The concentration of these pollutants usually depends on the time since the previous storm, and intensity and amount of rainfall. The efficiency of the gutter and storm sewer system can greatly affect the size and timing of peak flows collected by the system.

Mammoth Lakes is the only community in Mono County with an engineered stormwater collection system. In 1984, only a few parts of the community of Mammoth Lakes had storm drains. Most of the town was drained by a combination of natural and constructed surface channels, which led to a variety of drainage problems (Brown and Caldwell, 1984). Up until the late 1980s, much of the runoff from the developed area flowed as sheet-flow to roads or flowed in unimproved channels or ditches to topographically lower channels. In 1976, a storm drain system was constructed for a portion of the town, which eventually discharged directly to Murphy Gulch (Brown and Caldwell, 1984).

In association with the Main Street storm drain, a 260,000 ft^3 siltation basin was constructed at the downstream end of the Murphy Gulch channel, approximately 1/4 mile above its junction with Mammoth Creek. Although the basin trapped a significant volume of silt and sediment each year, there was evidence that it did not capture enough of the sediment input. During peak runoff, sediment deposition efficiencies are drastically reduced (due to high flow-through velocities), resulting in visibly turbid effluent discharges. The old earth-fill dam was in relatively poor condition as of 1984, and there were signs of seepage on its downstream face (Brown and Caldwell, 1984).

The drainage master plan proposed by Brown and Caldwell (1984) included construction of new storm sewers, capture of runoff that formerly went directly into Mammoth Creek, detention storage of runoff, additional local sediment retention basins, and reconstruction of the sediment retention basin in Murphy Gulch. The estimated capital cost was $18 million, and annual operating costs were estimated at $100,000 to $250,000 (Brown and Caldwell, 1984). In the early 1980s, about 1,600 acres of the town of Mammoth Lakes' area of four square miles (about 60 percent) were considered to be impervious (Environmental Sciences Associates, 1984). Summer rain events and winter rain-on-snow events can produce localized flooding in Mammoth Lakes, particularly within the lower-income neighborhoods. Funding from the Round 2 Prop. 84 Planning Grant will be used to develop a stormwater master plan for Mammoth Lakes.

The Indian Wells Valley contends with its own stormwater, drainage, and flooding issues, primarily resulting from heavy rains during the summer monsoon season. Although there is anecdotal evidence as to the frequency and severity of these events, there is a need to better quantify such events to improve stormwater planning and management.

Wastewater Treatment and Disposal

The cities, towns, and larger communities of the planning region have wastewater collection and treatment systems, while smaller communities and isolated homes do not. In the north, residences and businesses in Coleville and Walker rely on septic tanks and leach fields for sewage disposal. There are concerns about effectiveness of some of these systems in areas with high water tables. The USMC Mountain Warfare Training Center has a 100,000 GPD package waste treatment plant and leach fields (Mono County, 1992).

The Lee Vining Public Utility District sewage system includes the main part of town, but not the SCE plant, the Mobil station or the Pumice Plant. Waste enters into a large community septic tank, which is pumped periodically. The effluent passes through the septic tank into sewage ponds located below the community center. Mono City, Conway Ranch, Lundy Canyon, and other scattered homes are on individual septic systems.

The June Lake Public Utility District provides sewerage service to three major service areas: June Lake Village, Down Canyon, and the U.S. Forest Service's Silver Lake Tract. Additional service is provided by contract to campgrounds and several parking facilities along the June

Lake Loop (Boyle Engineering Corporation, 2005). Between 1995 and 2003, daily flow at the treatment plant ranged from 0.16 to 0.4 mgd with an average of 0.25 mgd. Based on an average daily water demand of 0.34 mgd, about three-quarters of the supplied water is returned to the sewer system. The remainder is presumably used for landscape irrigation. Average monthly flows ranged from 5.1 million gallons to 10.5 million gallons with an average of 7.6 million gallons. The projected average daily wastewater flow at buildout of the service area is 0.66 mgd (Boyle Engineering Corporation, 2005).

The primary wastewater treatment facility within the upper Owens River watershed serves the town of Mammoth Lakes (and cabins and campgrounds upstream of town) and is operated by the Mammoth Community Water District. An annual average of 1,500 acre-feet of water was treated at the facility between 1983 and 1997 (Bauer Environmental Services, 1998). In 2005 and 2010, 1,920 and 1,430 acre-feet of water was treated at the facility, respectively, (Mammoth Community Water District 2011a). The disinfected secondary-treated effluent from the facility is piped several miles to the Laurel Ponds where it is discharged. The treated water percolates into the ground at this location or evaporates. The maintenance of Laurel Ponds to at least 18 acres of surface area is considered beneficial for waterfowl by the Inyo National Forest, which administers the site. The Mammoth Community Water District recently completed a project to treat the wastewater to Title 22 standards for unrestricted irrigation use and began delivering reclaimed water to one of two local golf courses in 2010. The Mammoth Lakes wastewater treatment plant is a permitted wastewater facility as are the treatment plants of the Hilton Creek Community Services District, Mammoth Mountain Ski Area, and Convict Lake campground.

In the mid-1970s, the community of Hilton Creek/Crowley Lake had an estimated population of about 300 and was served entirely by individual disposal systems consisting primarily of septic tanks and leach fields or leach pits. Because of the presence of adverse soil and groundwater conditions, these individual systems had abnormally high failure rates for many years. Many of the disposal systems were located less than 100 feet from surface waters or in areas of shallow groundwater. Percolation rates throughout the community area are quite high, which is typical for glacial outwash soils. About two-thirds of the residences and at least five commercial establishments in the community obtained their domestic water supplies from the direct diversion of the surface waters of Hilton Creek. Mono County health officials were aware of problems from at least 1966. A study prepared by the Lahontan RWQCB for the county in that year reported alarming coliform concentrations at sample points in natural surface streams as well as in private water supply systems. The report attributed the majority of this contamination to the use and misuse of septic tank / leach field sewage disposal systems. Water quality sampling and public health investigations in the vicinity of Hilton Creek indicated that the continued use of individual disposal systems posed significant health hazards and adverse water quality impacts. Mono County and the Lahontan RWQCB both adopted restrictions and prohibitions on the installation of new septic tank / leach field disposal systems within the Hilton Creek service area in 1976. Furthermore, the Lahontan RWQCB prohibited use of existing disposal methods after January 1, 1985, and recommended that a community sewerage system be constructed for the area (Gram/Phillips, 1977).

The communities of southern and eastern Mono County rely on septic tanks and leach fields for sewage disposal as do most of the smaller communities of Inyo County.

The City of Bishop Public Works Department provides sewer service to the central portion of Bishop. A gravity collection system routes sewage to the wastewater treatment plant east of town. The plant processes about 800,000 gallons per day and has a capacity of 1.6 million gallons per day. Average wastewater flow is forecast to be 4.7 million gallons per day if Bishop was fully built out, including lands currently owned by the Los Angeles Department of Water and Power within the city limits (Nolte Associates, 2008b). One week per month, the City's wastewater treatment plant also treats sewage from the Eastern Sierra Community Services District, which operates its own treatment plant the other three weeks per month.

Other agencies that provide wastewater collection, treatment, and disposal services in Inyo County include Big Pine Community Services District, East Independence Sanitary District, Lone Pine Community Services District, and Inyo County.

The City of Ridgecrest's wastewater treatment system collects, processes, and disposes domestic wastewater from the city of Ridgecrest and the Naval Air Weapons Station at China Lake. The treatment facility has a design capacity of 3.6 million gallons per day and was treating an average of 2.6 million gallons per day in 2000, or about 2,900 acre-feet per year. About one-third of the effluent evaporates, and the remainder percolates to groundwater. As of 2010, a proposed solar electricity generating facility was pursuing use of the treated effluent as a coolant.

Description of Water Quality

Compared to most of California, water throughout most of the Inyo-Mono IRWM planning area is of very high quality, simply because of the small population and high proportion of public lands. There are not many opportunities for contamination compared to parts of the state with high population, industries, and intense land uses. Many of the identified water-quality issues in the Inyo-Mono planning region result from naturally-occurring minerals.

The Lahontan RWQCB water body fact sheet for the West Walker River lists sedimentation, agricultural drainage, and water diversions as the primary water-quality problems in the West Walker River. The State of Nevada considers the water crossing the state line to not support beneficial uses because of excessive nutrient load. Similarly, the Lahontan RWQCB identified sedimentation, ammonia, fecal coliform, and metals as problems in the East Walker River. Bridgeport Reservoir has been known to have high nutrient loads and consequent excessive primary productivity for at least 20 years. The Lahontan RWQCB has established a "conditional waiver" program for the agricultural lands of the Bridgeport Valley as a means of cooperatively reducing discharge of nutrients and bacteria from the grazing lands.

The Lahontan Basin Plan of 1975 characterizes the waters of the Mono Basin as generally excellent in quality, with total dissolved solids (TDS) levels of less than 50 parts per million (ppm) in surface water and less than 100 ppm in groundwater. Surface water is ionically dominated by calcium carbonate and classified as soft. Heavy metal concentrations are below detectable limits or only present in trace amounts. Dissolved oxygen is at or near saturation. Coliform bacteria are below detectable limits in groundwater; surface waters were not analyzed for bacteria (Triad Engineering, 1987). Independent sampling by Lee (1969) in several Mono Basin streams including Mill and Wilson creeks found that the waters were calcium bicarbonate type and had TDS ranging from 31 to 81 ppm.

Water quality in the major tributaries (Lee Vining, Walker, Parker, and Rush creeks) is typical of eastern Sierra Nevada snowmelt runoff streams. This area is largely undeveloped and undisturbed above the LADWP diversion structures, except for recreation-residential developments near June Lake and on Rush and Walker creeks and recreational facilities on Lee Vining Creek and Mill Creek. Natural weathering and erosion processes are the main factors affecting water quality in these streams. A seasonal difference in quality between groundwater-fed baseflow and snowmelt runoff has been measured (Jones and Stokes Associates, 1993b).

The upper Owens River watershed is used as a water source for export to the city of Los Angeles. Although geologic sources contribute phosphates, arsenic, and other minerals to the water, the overall quality is still excellent and quite suitable for human consumption at its urban destination.

The first Basin Plan for the Lahontan Region (Lahontan RWQCB, 1975) mentioned that analyses of water entering Crowley Lake found excellent quality for constituents measured except for arsenic, which sometimes exceeds federal drinking water standards. Most environmental documents relating to parts of the watershed routinely cite excellent water quality in the area's streams that is suitable for all beneficial uses. The principal exception is Mammoth Creek within and downstream of the town of Mammoth Lakes.

A major assessment of surface water quality in the Mammoth Creek watershed was conducted by a team of graduate students and faculty from UCLA in the summer of 1972 (Perrine, et al., 1973). This study judged the overall surface water quality to be excellent with respect to chemical constituents. One exception to the low chemical concentrations was relatively high concentrations of phosphorus that could contribute to excessive growth of aquatic plants, although natural sources were believed responsible. Fecal coliform bacteria counts in lower Mammoth Creek were high and believed to result from leaching from campground pit toilets in the Lakes Basin, septic systems in Old Mammoth, and pet waste. This study was conducted before the connection of the campgrounds and many of the houses in Old Mammoth to the sewer system. Several of the groundwater production wells in the Mammoth Lakes basin contain unsafe levels of arsenic that become problematic when water supplies are heavily dependent on groundwater contributions.

Over the entire Inyo National Forest (lands in the upper Owens River watershed are not distinguished separately), 97 percent of the water flowing off the forest was judged to meet water quality objectives as of 1988. The remaining 3 percent contained excessive sediment (USDA-Forest Service, 1988).

Water samples from various tributaries to the Owens River have been analyzed by LADWP since the 1930s and 1940s. During the Mono Basin Environmental Impact Report process, these data were summarized along with a special water quality survey in 1991 by Jones and Stokes Associates (1993b). All except Hot Creek had low concentrations of minerals and nutrients.

Every two years, the State Water Resources Control Board submits a report on the quality of streams and lakes in California to the U.S. Environmental Protection Agency. Part of that report refers to section 303(d) of the federal Clean Water Act, which directs the states to identify priority water quality issues in individual water bodies. The following water bodies in the Inyo-Mono IRWM region were on the 2010 list:

Table 2-12. Water bodies in the Inyo-Mono planning region on the 2010 impaired water bodies list from SWRCB.

Name	Pollutant
Amargosa River	Arsenic
Bodie Creek	Mercury
Bridgeport Reservoir	Nitrogen, phosphorus, sediment
Buckeye Creek	Pathogens
Crowley Lake	Ammonia, dissolved oxygen
East Walker River above BP res.	Pathogens
East Walker River below BP res.	Manganese, sediment, turbidity
Haiwee Reservoir	Copper
Hilton Creek	Dissolved oxygen
Mammoth Creek	TDS, mercury, metals
Mesquite Springs	Arsenic, boron
Mono Lake	Salinity, TDS, chlorides
Pleasant Valley Reservoir	Organic enrichment, dissolved oxygen
Robinson Creek	Pathogens
Rock Creek	TDS
Searles Lake	Salinity, TDS, chlorides, petroleum HC
Swauger Creek	Pathogens, phosphorus

Constituents: Measurements and Biological Indicators

Systematic sampling of water quality parameters has not occurred in the Inyo-Mono IRWM planning area. Therefore, our knowledge about region-wide water quality is based on irregular reporting of isolated sampling and analysis done sporadically over the past few decades.

Sediment

The Environmental Impact Statement for the Land and Resource Management Plan ("Forest Plan") of the Inyo National Forest (USDA-Forest Service, 1988:315) states that the "primary threat to water quality on the Inyo is sedimentation." The document indicates that the most significant sources of sediment are the ski areas and rangelands, particularly wet meadows, disturbed by historical overgrazing. In a subsequent section on cumulative effects that also addresses sources on private land, the Forest Plan states that suspended sediment in Mammoth Creek during spring-summer runoff increases ten-fold between the outlet of Twin Lakes and U.S. Highway 395.

Photo 3.31

Measurements of suspended sediment, turbidity, or bed load are not known to have been made within the Mono Basin until the past few years. A study of sediment budgets (R2 Resource Consultants, 2000) estimated about 13 acre-feet of sediment supply per year for Lee Vining Creek (range 3.0-2,770), about 0.9 acre-feet for Walker Creek (range 0.2-40), and about 3.8 acre-feet per year for Parker Creek (range 0.8-35). The various dams across Rush, Lee Vining, and Mill creeks have retained most of the sediment produced in the headwater areas and have increased channel scour below the dams to an unknown extent.

The June Mountain Ski Area was reported to produce "considerable sediment during peak runoff periods, causing a shutdown of water treatment systems for 30 days or more each year. Implementation of the [erosion prevention program] for the ski area has reduced these impacts over the past few years, and discharge will soon meet state requirements" (USDA-Forest Service, 1988).

The Inyo National Forest (1988b) has noted a significant increase in sediment and turbidity levels during peak runoff events in Mammoth Creek. These increases appear to be the result of disturbances in the developed area and the sensitivity of the local soils to disturbance. The impact of runoff from urban development is reflected in the increase in sediment and turbidity levels in Mammoth Creek as it flows through the town. Based on USFS data developed on Mammoth Creek at U.S. Highway 395 from October, 1981, to September, 1982, the total annual sediment discharge is estimated to be 5,100 tons or approximately 0.20 ton/acre of watershed. This sediment yield is one-third of the average for the Sierra Nevada (0.75 ton/acre) and one-tenth of the average for California (2 ton/acre) (Kattelmann, 1996).

Minerals

The limited water quality data suggest that the mineral content of the Mono Lake tributaries is very low and similar to other high quality Sierra Nevada streams. Concentrations of all minerals that were measured were low enough to rate as excellent drinking water quality (Jones and Stokes Associates, 1993b).

Total dissolved solids (TDS) were measured in samples collected from Mammoth Creek and some of the lakes in the Mammoth Lakes Basin during the summer of 1972 by the UCLA team and found to be generally less than 50 mg/l, with a couple of samples around 100 mg/l (Perrine, et al., 1973). Drinking water standards are about 500 mg/l for comparison. Measured concentrations of sodium, calcium, and magnesium were less than 10 mg/l. The Mammoth Community Water District has measured water from Lake Mary for various constituents since 1983. Values for TDS over this period have ranged from 10 to 50 mg/l with a mean of 31 mg/l.

Conductivity is often used as a proxy for TDS because it is relatively easy to measure. Specific conductance of water released from Grant Lake reservoir has been monitored by LADWP since 1934 and has ranged from 40 µS/cm to 100 µS/cm with an average of about 60 µS/cm (Jones and Stokes Associates, 1993b). Specific conductance was also measured for many years in Lee Vining Creek and found to range between 25 and 75 µS/cm.

Table 2-13. Spot measurements of conductivity made in various portions of the upper Owens River watershed during October 1985 by the Department of Fish and Game (Deinstadt, et al., 1986)

Waterway	Conductivity (µS/cm)
Owens River	120, 130, 120, 170
Rock Creek	20, 25, 30, 20, 8
McGee Creek	40, 75, 70
Mammoth Creek	77, 85, 128, 108, 115, 35
Hot Creek	580
Laurel Creek	50
Sherwin Creek	20
Glass Creek	30

Table 2-14. Conductivity measurements by LADWP and Jones and Stokes Associates (1993b)

Waterway	Conductivity (µS/cm)
Owens River at Big Springs	166-223
Owens River at Benton Crossing	295-560
Mammoth Creek	50-200
Hot Creek	200-650
Convict Creek	125-175
McGee Creek	56-175
Hilton Creek	24-62
Crooked Creek (1991 only)	43-128
Rock Creek	25-125

Nutrients

Nutrient loading is a major issue in the East Walker River basin. Bridgeport Reservoir is eutrophic and is afflicted with blooms of blue-green algae each summer. The Bridgeport Valley upstream of the reservoir is extensively grazed from June through September. Phosphorus and pathogen concentrations in tributaries to Bridgeport Reservoir, measured in April-June, 2000, increased significantly downstream of pastures (Horne, et al., 2003). However, biochemical processes in the wet soils of the pastures are converting and capturing most of the applied nitrogen (Horne, et al., 2003).

Limited sampling suggests very low concentrations of nutrients in streams of the Mono basin. The 1991 sampling of Grant Lake found only minimal concentrations of nitrogen and phosphorus, both in the lake and the outlet. Chlorophyll *a* values in Grant Lake reservoir ranged from 0.9 to 13.3 µg/l, with an average of 5.8 µg/l, indicating low nutrient status and consequent low biological productivity (Jones and Stokes Associates, 1993b).

A mix of historical water quality results reported by the Los Angeles Department of Water and Power (1984) included measurements of nitrate that ranged from 0 (below detection) to 2 mg/l. Besides that one value of 2 mg/l, all other reported values were 0.4 mg/l or less.

In June Lake, nutrient concentrations from limited sampling were quite low with combined nitrate plus nitrite concentrations below detection in three samples and 0.02 mg/l in a fourth sample. Ammonia was 0.03 mg/l or less. Orthophosphate was not detected, and total phosphorus concentrations were 0.02 mg/l or less (Brown, 1979). This study found that although nitrate plus nitrite was below detection limits in Gull Lake, concentrations of ammonia and orthophosphate were relatively high: up to 0.54 and 0.16 mg/l, respectively. Both nutrients were believed to be derived from anaerobic decomposition of algae and other organic matter in the near-bottom layers of the lake (Brown, 1979). The study hypothesized that nutrients released from the surrounding homes prior to the sewer system might contribute to the high fertility of Gull Lake (Brown, 1979).

In Silver Lake, nutrient concentrations were below detection limits except for total phosphorus concentrations of 0.01 and 0.02 in two samples. The study judged that there was a minor enrichment of Silver Lake from nutrients contributed by Gull Lake via Reversed Creek (Brown, 1979).

The 1994 samples from Rush Creek above Grant Lake (USGS station 10287400) and the Rush Creek power plant tailrace (USGS station 10287300) had the following results (concentrations in mg/L):

Table 2-15. Rush Creek nutrient concentrations as measured in 1994

Rush Creek Nutrient Concentrations	
Total nitrogen	< 0.05
Ammonia	0.01-0.02
Phosphorus	<0.01-0.02
Orthophosphate	<0.01

The nutrient budget of Crowley Lake has received greater attention than other parts of the Inyo-Mono IRWM planning area because of the eutrophic state of the reservoir. Almost all (96 percent) of the observed phosphorus loading to Crowley Lake comes from the Owens River, which only provides about half of the water input to the lake (Jellison and Dawson, 2003). The known sources for this phosphorus are Big Springs and numerous sites along Hot Creek.

The Owens River accounts for 79% of the nitrogen input to Crowley Lake and McGee Creek accounts for 13% (Jellison and Dawson, 2003). Ammonia, nitrate, and total nitrogen concentrations are relatively low in all other tributaries. Total nitrogen concentrations increased somewhat across the irrigated pastures of Convict and McGee creeks. This increase is about 6 percent of total nitrogen loading to Crowley Lake. Hot Creek fish hatchery contributes a significant amount of ammonia and total nitrogen to Hot Creek. The communities of Mammoth Lakes, McGee Creek, and Hilton Creek had little apparent effect on nutrient concentrations downstream (Jellison and Dawson, 2003). Three to four times more nitrogen leaves Crowley Lake than enters it, presumably because of nitrogen-fixing cyanobacteria (blue-green algae) in the lake.

Nitrate concentrations were measured in Mammoth Creek in the summer of 1972 by the UCLA team and were less than 0.5 mg/l in 99 percent of the samples (Perrine, et al., 1973). Phosphate concentrations were generally less than 0.1 mg/l, although a few samples were up to 0.3 mg/l.

There is potential, but no direct evidence, for contamination from excessive use of chemical fertilizers on gardens, lawns, and parks. Nutrients from fertilizers that are not incorporated in plant tissue can be leached from soils and enter local streams.

Metals

Mercury has been a concern in the Walker River basin after elevated concentrations of mercury were found in tui chub and common loons at Walker Lake. Recent sampling of water, sediment, and aquatic invertebrates suggests that the primary source areas are associated with the Bodie and Aurora mining districts in the Rough Creek watershed, which is part of the East Walker basin. Samples from the West Walker River had total mercury concentrations within the range of natural background amounts: 0.62 ng/L in the water and 8 to 44 ng/g in the sediment (Seiler, et al., 2004). By contrast, the East Walker River above the confluence with the West Walker had a total mercury concentration of about 60 ng/L in the water and more than 1,000 ng/g in the sediment. The greatest total-mercury concentration in sediment was found in

the bed of Bodie Creek at 13,600 ng/g (Seiler, et al., 2004). The absence of major mining and milling operations in the West Walker watershed appears to have minimized mercury contamination in marked contrast to the adjacent Carson and East Walker rivers.

Trace element concentrations were frequently undetectable or very low in water at the Grant Lake reservoir outlet, but lead, zinc and boron were found in sediments in concentrations slightly higher than background (Jones and Stokes Associates, 1993b).

The 1994 samples from Rush Creek above Grant Lake (USGS station 10287400) found concentrations of boron between 10 and 20 mg/L, concentrations of iron between 12 and 24 mg/L, and concentration of manganese between 3 and 11 mg/L.

Metals, primarily arsenic and mercury, have been measured in the Crowley Lake water column and sediments (as has uranium more recently; Lahontan RWQCB, 1994). These substances are believed to originate from natural sources resulting from the particular chemical composition of the watershed's geology. Arsenic concentrations high enough to be a health concern for fish and humans have been measured in the upper Owens River below the confluence of Hot Creek as well as in Hot Creek itself (Ebasco Environmental, et al., 1993). A detailed study of arsenic in Crowley Lake waters confirmed the geologic nature of the sources (Jellison, et al., 2003).

When the level of Crowley Lake fell rapidly in 1989, tributary streams eroded new channels in their deltas in response to the dropping base level. Large volumes of sediments were transported into deeper areas of the lake. Stirring up these sediment deposits also released mercury that had been in storage, and elevated mercury levels were found in water samples collected by LADWP at the dam in February 1990 (Milliron, 1997). Subsequent analyses of trout tissue found no detectable levels of mercury or other heavy metals (Milliron, 1997).

Organics

In 1999, the June Lake Public Utility District tested all its water systems for various organic chemicals. Dichloromethane, an insecticide and industrial by-product, was detected in water from June Lake and Snow Creek in one sampling but not found again in follow-up tests (Boyle Engineering Corporation, 2004). No other records of analyses of organic contaminants for the Mono Basin were located.

Fuel spills from crashes of tanker trucks have contaminated Slinkard Creek and the East Walker River in recent years. Major clean-up operations were performed in both cases. Fuel spills may have occurred within the June Mountain Ski Area during slope grooming operations.

Monitoring wells at the Benton Crossing landfill have detected low concentrations (about one or two parts per billion) of three volatile organic compounds (Mono County Planning Department, 2004). Although the concentrations appear to be stable and well below the so-called maximum contaminant levels, a monitoring program reports results from sampling and analysis to the Lahontan Regional Water Quality Control Board.

Temperature

Temperatures of stream water are determined by the source of water (direct snowmelt runoff, overland flow, and seepage from soil and groundwater) and energy inputs (primarily solar radiation). Shading of the stream by terrain features and vegetation regulates the amount of solar energy received by the water. The volume of flow is also critical because a given amount of energy can raise the temperature of a large volume of water only a small amount but can raise the temperature of a small volume perhaps several degrees.

Herbst and Kane (2004) found that summer stream temperatures rarely exceeded 59°F in the control streams of their study within the West Walker River watershed. Summer temperatures of some of their treatment streams that had comparatively little riparian vegetation were well above 59°F. Maximum temperatures in their Poore Creek site exceeded 80°F in 2002.

Water temperature in the streams of the Mono Basin has been altered by water management activities. Water is stored in several reservoirs in the Mono Basin where the timing of the releases affects the volume of water in the stream, and the depth of the outlet determines whether warm surface water or deeper cool water enters the stream below the dam. The diversions for export greatly reduced flow and consequently raised temperatures below the diversions. Flow reductions also decreased the amount of riparian vegetation that provided shade to the streams.

Water temperatures were monitored at four locations on the upper Owens River between June 1 and September 30, 1991 (Ebasco Environmental, et al., 1993). The average temperatures, as well as the variation in daily temperature values, tended to increase downstream. Daily average temperatures ranged from 52°F to 65°F at the powerline crossing above Hot Creek and from 56°F to 72°F at Benton Crossing. Maximum temperatures ranged up to 80°F (Ebasco Environmental, et al., 1993).

Water temperatures in upper Mammoth Creek were measured during the summer of 1972 and found to be in the range of 54°F to 75°F and did not exceed 82°F. The daily temperature range varied within 2°F to 10°F (Perrine, et al., 1973).

Water temperatures in Hot Creek and Convict Creek apparently rise several degrees where warm irrigation return flow enters the creeks following flood irrigation of adjacent pastures.

Dissolved Oxygen

Limited sampling above and below Topaz Reservoir suggested that stratification of the stored water behind the dam results in less dissolved oxygen downstream of the reservoir than is present in the West Walker River upstream (Humberstone, 1999).

June Lake mixes twice a year, usually in May and October. In summer and winter, June Lake is stratified with dissolved oxygen near saturation (and therefore favorable to trout) only at middle depths during summer (Brown, 1979). Decomposition of organic matter, mainly algae, depletes the oxygen below about 50 feet in June Lake. In Gull Lake, dissolved oxygen was not present below 40 feet, and the lake was judged to be eutrophic with excessive algal productivity. Dissolved oxygen in Silver Lake was near saturation except for some depletion noted in a 1979 sample (Brown, 1979).

Dissolved oxygen levels in upper Mammoth Creek were measured in the summer of 1972 by the UCLA team and found to be 6 to 8 mg/l, a range quite suitable for trout and close to theoretical saturation at the ambient temperatures of the streams and lakes (Perrine, et al., 1973). This study also found biochemical oxygen demand in Mammoth Creek was quite low, almost always below 2 mg/l.

Dissolved oxygen was measured in Crowley Lake during August, 1993 (when the lake was stratified), by the Department of Fish and Game. Below a depth of 33 to 43 feet, dissolved oxygen was only 2 mg/l (Milliron, 1997). Concentrations of dissolved oxygen between 3 to 5 mg/l restrict growth of trout, and levels below 3 mg/l can be lethal to trout after long exposure (Milliron, 1997).

Pathogens

The UCLA team measured concentrations of total coliform and fecal coliform bacteria in water samples from Mammoth Creek and lakes in the Lakes Basin during the summer of 1972. This study found a wide range of variability from 0 to 10,000 colonies per 100 ml for total coliform and 0 to 1,000 colonies per 100 ml for fecal coliform (Perrine, et al., 1973). Naturally occurring soil bacteria were believed to be the main constituent of the total coliform counts. The highest fecal coliform counts were found in lower Mammoth Creek and believed to result mainly from leaking septic systems in Old Mammoth and pet waste.

Most sites sampled by Setmire (1984) in upper Mammoth Creek had fecal coliform bacteria counts below 10 colonies per 100 ml. Mammoth Creek at U.S. Highway 395 had 250 colonies per 100 ml, and Hot Creek below the hatchery had more than 1,000 colonies per 100 ml (Setmire, 1984).

There have been anecdotal reports of bacterial contamination of the small channels over the Hilton Creek fan (Hilton Creek distributaries) by neighboring outhouses and septic systems. For example, a routine water sample within the Crowley Lake Mutual Water Company system tested positive for fecal coliform in November, 2002 (Mammoth Times, 2002).

pH and Alkalinity

The pH of water is an index of the hydrogen ion concentration, which in turn causes water to be acidic or alkaline. A pH value of 7 is neutral, values less than 7 (increasing hydrogen ion concentration) are acidic, and values greater than 7 [to a maximum of 14] (decreasing hydrogen ion concentration) are alkaline. Lakes in the upper Owens River watershed had pH values averaging about 8.3 in an early survey. Slightly alkaline waters such as these lakes tend to have more plants and animals than neutral or acidic waters.

Alkalinity is a measure of the capacity of water to buffer changes in hydrogen ion concentration. Water with greater alkalinity is more resistant to changes in pH. Alkalinity depends on the amount of carbonate, bicarbonate, and hydroxide ions.

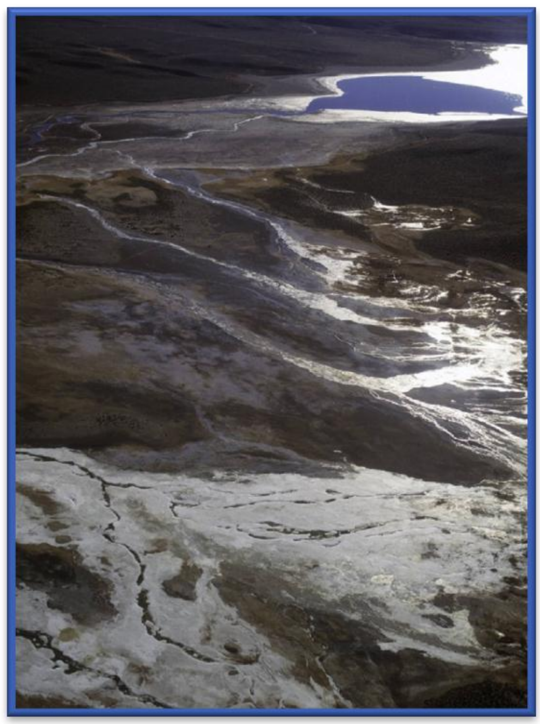
A study of Crystal Lake relating to acidic precipitation found that the pH of the lake was 6.7 to 6.1, and the acid-neutralizing capacity varied from 56 to 82 microequivalents per liter (µeq/l). Acid-neutralizing capacity declined rapidly during the snowmelt season as very pure runoff water entered the lake, and then slowly increased during the remainder of the year (Melack, et al., 1992).

Water imported from the Mono Basin lowered the alkalinity of the upper Owens River and consequently might have had some potential effects on the toxicity of naturally occurring metals.

Groundwater Quality

Boron, fluoride, and arsenic have been found in water from artesian wells near the center of Antelope Valley. Among five wells sampled in Antelope Valley, one had a concentration above a Maximum Contaminant Level for inorganics-primary, and two had a concentration above a Maximum Contaminant Level for radiological (DWR, 2004).

Occasional measurements of samples from wells and springs have been made over the years. For the Mammoth Creek watershed, the California Department of Water Resources (1973) reports TDS and electrical conductivity for several dozen wells and springs. TDS values ranged from 30 to 300 mg/l for cold water sources and 500 to 1,600 mg/l for geothermal sources. Electrical conductivity ranged from 60 to 400 micromhos/cm for cold water sources and between 500 and 2,300 for geothermal sources.



Water issuing from the Mammoth Mine adit had a TDS concentration of 95 mg/l, and a spring near the YMCA camp had an electrical conductivity of 50 micromhos/cm (DWR, 1973).

Some of the groundwater pumped by MCWD contains arsenic. After treatment, the average arsenic concentration in MCWD supplies is below the maximum contaminant levels (MCL). In April, 2009, MCWD conducted a public notification when arsenic MCLs were exceeded. In 2009, the average arsenic level was 8.9 parts per billion, with a range of 0 to 33 ppb (I. Yamashita, personal communication). The drinking water standard for arsenic was changed from 50 ppb to 10 ppb in January, 2006. MCWD has instituted changes to its pumping management and made improvements to its water treatment operations to meet the revised arsenic MCLs.

In recent years, the presence of uranium compounds at concentrations above drinking water standards has been identified in some community water supplies and private wells within the region. Trace amounts of uranium occur in some of the geological substrates of the area, and local groundwater partially reflects the chemical composition of materials in contact with the water. The extent and severity of the issue is uncertain as of 2010. The Environmental Health Department of the County of Mono is monitoring the situation. The next iteration of this plan should contain additional details.

Groundwater in the vicinity of the Benton Crossing landfill is monitored with a series of wells to detect any changes in groundwater quality resulting from materials leaching out of the landfill.

As of 1998, there were 12 known cases of leaking underground storage tanks (presumably gasoline or other volatile fuels) within the upper Owens watershed (Lahontan Regional Water Quality Control Board, 1998). A large gasoline spill occurred at the Mammoth Mountain garage facility on January 12, 1999 (Buckmelter, 2000). Approximately 7,500 gallons of gasoline entered the soil, and about a quarter of that amount was recovered within the first few months after the spill. A series of monitoring wells was installed to observe the plume within the groundwater.

Some overly generalized information on groundwater quality for Long Valley between 1994 and 2003 was tabulated in a recent report of the California Department of Water Resources (2004). Two of six public supply wells tested in Long Valley exceeded the maximum contaminant levels for radiological contaminants. All four of the public supply wells tested in Long Valley exceeded the maximum contaminant level for some inorganic secondary contaminant (chloride, copper, iron, manganese, silver, specific conductance, sulfate, total dissolved solids, or zinc).

In recent years, one of the wells supplying water to the Mountain Meadows Mutual Water Company for part of the Hilton Creek/Crowley Lake community has had concentrations of uranium sufficiently high to be a matter of concern.

Natural Sources of Constituents

Big Springs and Deadman Creek provide natural sources of phosphorus, which encourages abundant growth of aquatic plants in the upper Owens River and in Crowley Lake. Big Springs was found to be the primary source of phosphorus for Crowley Lake (Melack and Lesack, 1982). Hot Creek is the largest tributary to the upper Owens River and contributes additional nutrients as well as some heavy metals. Arsenic is found at high levels in some of the Hot Creek geothermal springs within the creek (Ebasco Environmental, et al., 1993).

Anthropogenic Sources of Constituents

A water quality modeling study demonstrated that reducing diversions from the West Walker River would improve water quality in the river as well as Walker River, largely by providing additional water for dilution of dissolved salts (Humberstone, 1999).

A recent study in the Bridgeport Valley (Elkins, 2002) may provide some indications about nutrient and fecal coliform pollution from livestock operations. Elkins (2002) found that:

1) more than half of the annual nitrogen and phosphorus loads to Bridgeport Reservoir were delivered by snowmelt runoff,
2) total inorganic nitrogen (nitrate and ammonia) was removed by biochemical processes in the saturated soils of the Bridgeport Valley,
3) water that remained in the channels and was not in contact with the soils retained any inorganic nitrogen already present,
4) dissolved organic nitrogen was the primary form of nitrogen entering Bridgeport Reservoir and was readily leached from manure and irrigated soils,

5) phosphorus was not retained by the soils and was readily transported on eroded soil particles,
6) fecal coliform from livestock manure appears to survive for months even in the cold temperatures of Bridgeport Valley and is readily transported in snowmelt runoff and irrigation return flow.

Unpaved roads are the principal source of sediments from human activities throughout the Sierra Nevada (Kattelmann, 1996). That situation is likely to be the case within the Inyo-Mono IRWM planning area as well, although grading for residential construction may be the main source in local areas, such as the town of Mammoth Lakes. Activities that remove vegetation and leaf litter, expose soil directly to rainfall and runoff, and compact soil greatly increase the potential for erosion. If the disturbance is near a stream channel, then there is a high likelihood that the eroded sediment will be transported into a stream rather than just relocated. The Mammoth Mountain Ski Area was also identified as a major source of human-caused sediment (USDA-Forest Service, 1988). However, erosion control efforts and sediment detention basins have presumably greatly reduced the amount of sediment leaving the ski area boundaries.

A variety of petroleum- and rubber-based materials are washed off paved roads into storm sewers and small channels. Nitrogen and phosphorus enter streams from several sources: leakage and failure of septic and sewage systems; overapplication of fertilizers on lawns, gardens, golf courses, and ski runs; release of some household cleaning products; and pet waste. Pathogenic bacteria, such as *E. coli*, enter surface waters from leakage and failure of septic and sewage systems, pet waste, livestock waste, human waste from recreationists, and indiscriminate flushing of RV waste tanks.

A standard septic system uses a septic tank and a leach field. If properly designed, installed well above the water table and in adequately draining soil, constructed, and operated, then a regular septic system is capable of nearly complete removal of fecal coliform bacteria, suspended solids, and biodegradable organic compounds (EDAW, 2005). The most critical factor in determining effectiveness of septic systems for treating the contaminants above is the time that leachate takes to travel between the leach lines and the water table. Deep soils that drain slowly allow for maximum biological processing of the wastewater. Unfortunately, in most soils, septic systems are relatively ineffective for removing nitrogen, pharmaceuticals, and other synthetic organic compounds (EDAW, 2005).

The State Water Resources Control Board is currently (2006) drafting new regulations to address septic systems, also known as on-site wastewater treatment systems (OWTS). California currently lacks statewide regulations or standards on septic systems, and practices vary greatly between regional water quality control boards and local jurisdictions. Depending on what criteria are ultimately adopted, the new regulations could result in greatly increased costs for on-site wastewater disposal or building moratoria in some areas.

Description of Major Water-related Objectives and Conflicts

The objectives of the Inyo-Mono RWMG are thoroughly discussed in Chapter 7. Ongoing conflicts over water in the Inyo-Mono IRWM region as of 2012 are best seen in the context of historical water conflicts of the eastern Sierra Nevada.

Water-related conflicts in the Inyo-Mono IRWM region began soon after the arrival of Euro-American settlers in the 1850s. The most severe winter on record brought widespread flooding to the area in 1862. The scarcity of food and shelter amid the high water in the southern Owens Valley led to violent conflicts between native Paiutes and the new settlers (Chalfant, 1933; DeDecker, 1966).

As irrigation of fields and orchards throughout the Owens Valley grew rapidly in the late 1800s, discharge in the Owens River dropped dramatically and Owens Lake began to shrink. By 1890, about 250 miles of canals and ditches had been constructed with a combined capacity of about 1,200 cfs (exceeding flow the of Owens River much of the year). After the turn of the century, engineering plans, financing, deals for land and water rights, and construction were organized to move water from the Owens Valley to Los Angeles. With completion of the Los Angeles Aqueduct in 1913, water demand for export began to compete with water demand for local irrigation. From 1913 through 1922, the City of Los Angeles and Owens Valley irrigators apparently got along with an adequate distribution of water, largely because the intake for the aqueduct near Aberdeen was downstream of the principal agricultural areas of the valley (Vorster, 1992). An agreement was almost reached to guarantee water supplies to existing irrigated lands in 1913, but a legal challenge from a private citizen in Los Angeles disrupted the negotiations (Vorster, 1992). A series of dry years from 1921 through 1925 led to the City's effort of purchase additional land and water rights from 1923 through 1927. There is a wide range of accounts of the circumstances and practices of acquisition during that period (e.g, Chalfant, 1933; Hoffmann, 1981; Kahrl, 1982; Reisner, 1986; Smith and James, 1995). Despite much controversy surrounding the real-estate deals, actual prices paid for land and water rights in almost all cases were at least fair-market value and occasionally quite favorable to the sellers (Vorster, 1992; Libecap, 2007). Landless agricultural workers, especially Native Americans, lost work as cultivated acreage declined.

As growth accelerated in Los Angeles in the 1920s and 1930s, LADWP sought to increase its water supplies from the eastern Sierra Nevada. The City filed for appropriative water rights on streams in the Mono Basin, acquired streamside parcels in the Mono Basin, constructed diversion structures, built a dam forming Grant Lake reservoir, and tunneled through the Mono Craters to get water from the Mono Basin to the upper Owens River. Water began to flow through the Mono Craters Tunnel in 1941. Although initially considered in the 1920s, a second aqueduct was not designed until 1963 and completed in 1970. The resulting sixty percent increase in aqueduct capacity (480 cfs to 780 cfs) allowed for additional water exports from the Mono Basin, provided rationale to reduce irrigation of City-owned lands, and created an opportunity to export additional quantities of groundwater. All three activities had environmental consequences and led to strong objections from some eastern Sierra residents.

Inyo County filed a lawsuit in 1972 intended to force a reduction in groundwater extraction and export. The legal action used the new California Environmental Quality Act, and courts limited groundwater pumping by LADWP until an Environmental Impact Report was completed. While litigation proceeded in the courts, the county and city attempted to negotiate an agreement to meet the water needs of both regions (e.g, Smith and James, 1995). Focused primarily on groundwater management, the Inyo / LA Long Term Water Agreement provides the basis for resolving some of the conflicts over water allocation in the Owens Valley. A primary goal of the agreement was to "to avoid certain described decreases and changes in vegetation and to cause no significant effect on the environment which cannot be acceptably mitigated while providing a reliable supply of water for export to Los Angeles and for use in Inyo County." The agreement specifies baseline conditions for native phreatophytic vegetation, prescribes water supplies for irrigated areas, manages pumping according to soil water and vegetation conditions, provides for a number of mitigation projects, and puts in place technical and policy making committees (Harrington, 2012, personal communication).

The agreement also provided for the rewatering of the Owens River channel downstream of the primary intake for the Los Angeles Aqueduct. A 1997 Memorandum of Understanding expanded the scope and terms of the 62 mile-long "Lower Owens River Project" and provided for additional mitigation. Water was released into the channel in December, 2006, and flows are used to enhance the river's riparian corridor, improve wildlife habitat in the Blackrock and Delta Habitat Areas, and to maintain off-river lakes and ponds for recreation.

Although irrigation diversions had markedly reduced Owens River inflows to Owens Lake in the late 1800s and the lake's water level had dropped by about 33 feet between 1878 and 1905 (Lee, 1915), water export to Los Angeles beginning in 1913 completely diverted inflow from entering Owens Lake. By 1924, the lake was essentially gone, exposing over 60 square miles of lake bed and creating the largest monitored source of windblown dust (PM-10) in the United States. In 1987, the U.S. E.P.A. found that the southern Owens Valley was in violation, and subsequently in 1993, in "serious non-attainment" of PM-10 particulate matter air-quality standards. Because of the connection between removing the inflows to the lake and the consequent empty lakebed, the Great Basin Unified Air Pollution Control District, the California Air Resources Board and the U.S. Environmental Protection Agency determined the City of Los Angeles is responsible for controlling the air pollution emissions from the dry lakebed. In 1998, the Great Basin Unified Air Pollution Control District and the City of Los Angeles entered into a memorandum of understanding to control dust emissions from the lakebed. Over the past decade, the City has expended over a half billion dollars and has recently applied up to 76,000 acre-feet of water per year to control dust (Great Basin Unified Air Pollution Control District, 2008; LADWP, 2011a). An Owens Lakebed Master Plan is currently (December, 2010) being developed to resolve issues such as continued dust control and water use, wildlife habitat, and possible solar power generation at Owens Lake. The air pollution levels dropped about 90 percent between 2000 and 2009 as dust controls were implemented.

Following completion of the second aqueduct, export of water from the Mono Basin became a widely recognized controversy. When diversions out of the basin approximately doubled in 1970, the rate at which Mono Lake level dropped increased significantly, which resulted in increased salinity. In 1978, the Mono Lake Committee was formed with the initial goal of restoring Mono Lake back to the water level it had in 1976, which would limit some of the ecological consequences of diverting its tributary streams. The water diversion conflict in Mono County generated a large amount of press coverage and public attention. Inevitably, the issue entered the legal system. An initial suit, brought by the National Audubon Society, advanced relatively quickly on appeal to the California Supreme Court. The court's decision in February, 1983, found that the allocation of the waters of the Mono Basin needed to be reconsidered, based on public trust values. In autumn of 1984, another lawsuit based on a section of the California Fish and Game Code led to a decision to maintain flows below Grant Lake dam adequate to maintain the fishery that became reestablished during the big winters of 1982 and 1983. Further legal actions led to an injunction in 1991 to maintain the then-current lake level while the State Water Resources Control Board studied the diversions of water from the Mono Basin streams. In September, 1994, the Board issued its decision, amending the licenses so as to partially restore Mono Lake and its tributary streams (Hart, 1996).

Comparatively minor operational conflicts continue over the progress and form of Mono Basin stream restoration efforts. In the past decade, a local controversy has ensued over the distribution of water between Mill Creek and Wilson Creek in the northwestern part of the basin. The matter is expected to be addressed through the hydropower relicensing process of the Federal Energy Regulatory Commission.

At the north end of the planning region, the long-term trade-off between irrigation and maintaining Walker Lake is the fundamental conflict over water. The dramatic decline in the level and volume of Walker Lake and the consequent increase in salinity and changes in the lake's fishery have attracted national attention. Between 1882 and 1994, as irrigation consumed water from the Walker River, the surface elevation of Walker Lake fell by about 140 feet and the volume decreased by about 75 percent (e.g., Sharpe, et al., 2008; Collopy and Thomas, 2010). Concentration of salts has increased five-fold over this period. Anecdotal accounts suggest that Lahontan cutthroat trout ceased to exist within Walker Lake during 2009 or 2010 (e.g., Gregory, 2011). The volume of water subject to appropriation through existing water rights is 40 percent greater than the average annual inflow to the lake. Most of the water that actually reaches the lake enters during major floods that exceed the upstream capacity of storage reservoirs.

Although there is potential to improve water supplies by conjunctive use of groundwater and surface water and greater water conservation through ditch lining, upgrading distribution systems, and irrigation scheduling, the political will to acquire or alter water rights is lacking. Although the volume of water evaporated through irrigation on the California side of the stateline is small compared to that downstream in Nevada, opportunities for purchase or lease of water rights are being explored within the California portion of the basin.

The primary water issue within the upper Owens River watershed is supplying water for the town of Mammoth Lakes without adversely affecting aquatic habitat in Mammoth Creek or water quantity and/or temperature at the Hot Creek hatchery springs. This water supply concern has been a persistent issue since the 1970s and became more acute with the town's growth. In 2011, MCWD adopted a project described in an Environmental Impact Report identifying monthly Mammoth Creek flow amounts that would restrict diversions for town water supply. These flow amounts are intended to protect the aquatic habitat of the creek. In addition, in 2011, the District updated its Urban Water Management Plan that evaluates current and projected water supplies under various water year scenarios and compares these supplies with projected town growth. The UWMP concluded that the development of one new groundwater well and maintaining water conservation efforts will result in adequate supplies for projected town growth. Since these reports were completed, the City of Los Angeles, through the Department of Water and Power, has filed legal challenges to the UWMP and the District’s EIR addressing the environmental impacts of the District’s water right licenses and permit (Mammoth Community Water District, 2011b). These legal challenges generated uncertainties and controversies over supplying water to the town of Mammoth Lakes and the USFS recreational facilities in the Mammoth Lakes Basin. These matters were largely resolved with issuance of Amended Permit 17332 and Amended Licenses 5715 and 12593 to MCWD by the State Water Resources Control Board and a Settlement Agreement between MCWD and LADWP in July 2013. This agreement allows the District to divert up to 4,387 acre-feet per year from Mammoth Creek.

The development of geothermal energy near the junction of U.S. Highway 395 and State Route 203 has long been a concern to the Mammoth Community Water District (MCWD) with respect to potential impacts on groundwater resources. Potential interactions between pumping for water supply for the town of Mammoth Lakes and pumping for hot water for electrical generation have not be closely monitored. As of 2014, MCWD was pumping about 2,000 acre-feet per year from the “coldwater” aquifer at depths of 400 to 700 feet below the surface. In at least parts of the Mammoth Creek watershed, there is a zone of relatively warm water below this coldwater aquifer. Beneath the warm zone, temperature continues to rise, and water hot enough to extract for geothermal energy production can be found.

A proposed expansion of the geothermal energy facility, the Casa Diablo IV Geothermal Development project, would include 16 new wells that could extract 10,000 acre-feet of hot water per year. Current pumping for the geothermal plant is about 19,000 acre-feet. Almost all of the proposed geothermal wells are closer to the town of Mammoth Lakes and the water supply wells than the existing geothermal wells. These new wells would pump hot water from depths of about 1,500 to 2,000 feet below the surface. Because of the complex geology and little drilling data about the nature of the rock between the coldwater aquifer and the geothermal aquifer, potential connections for water and heat between the two layers are unknown. Therefore, whether extraction of underlying hot water would have any impact on the overlying coldwater aquifer is also unknown. MCWD has requested that the geothermal developer install additional monitoring wells and have a mitigation plan in case impacts are detected in the future.

The southeastern part of the Inyo-Mono region has been identified as a favorable location for solar power development. One project in the California portion of Pahrump Valley was in the California Energy Commission permitting process as of May 2012, and at least four other projects are in various stages of planning in the Nevada portion of the basin. Projects have also been proposed in the Middle Amargosa basin and Owens Valley. Water use by these projects depends on the power generation and cooling technology used, and because the southeastern part of the region has scant surface water, the water needs of these projects will be supplied with groundwater. Supplying large amounts of groundwater to projects in the southeastern part of the region may be problematic because the Nevada State Engineer has declared that the Pahrump basin is in overdraft.

Because of the lack of comprehensive data on the safe yield of the region's many isolated aquifers, new residential developments frequently face opposition based on the inadequacy of water supply data. Although the CEQA process addresses this issue and individual water availability analyses are performed, these studies are frequently viewed with skepticism by those within close proximity to the development, who fear their own water supplies will be impacted. Without major advances in localized groundwater data, this problem will likely continue. CASGEM reporting should provide much-needed information.

In the Mono Lake and Owens Rivers basins, about 460 miles out of 530 miles of streams are affected by water diversions (Inyo National Forest, 1987). During the 1980s, under the favorable conditions created by the Public Utilities Regulatory Policy Act, at least a dozen small-scale hydroelectric projects were proposed on streams of the eastern Sierra Nevada. None of those projects were built, although plans occasionally resurface (*e.g*, on Pine Creek).

Historical conflicts over water resources in the Inyo-Mono region have centered on water exports, impacts on closed-basin lakes, and groundwater pumping. Current conflicts seem both milder in intensity as well as focused on other issues, such as water quality, community water supply, water conservation, and allocations supporting environmental benefits. Today, the level of controversy within the region seems greatly reduced compared to our history. Although disagreements certainly persist over water in such an arid region, there appears to be a greater willingness by most parties to attempt to resolve differences though negotiation and collaborative processes and avoid litigation. The Owens Lakebed Master Plan effort and the Inyo-Mono Regional Water Management Group are examples of this current direction. We anticipate further progress in collaborative water resources management over the twenty-year planning horizon of this plan.